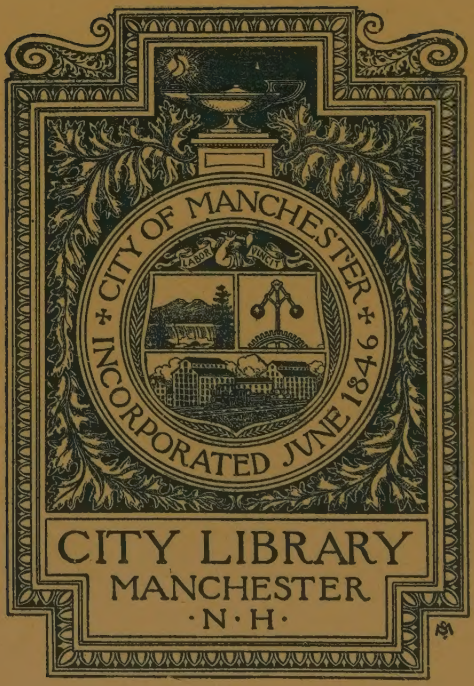
The Farmer of Tomorrow

Anderson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THE FARMER OF TO-MORROW

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THE FARMER OF TO-MORROW

BY

FREDERICK IRVING ANDERSON

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PREFACE

THE author has sought to bring together in one volume a popular consideration of the two fundamental factors affecting the business of farming: first, the floor space of the American farmer in terms of land, and, second, the resources of the land itself, in terms of soil fertility. The inter-relation of these two factors must determine eventually the type of farming of any community.

"Where shall I locate my plant?" is the prime question the man who goes back to the land to-day must ask himself. Free land is gone; the rich homesteads of a decade or two ago, to be had for the asking, have forever passed into history. Yet there are opportunities for the business farmers of to-day undreamed of by their ancestors of a generation or two ago to whom land was nothing but a means of labor. Less than one-half of the nine hundred million acres in the hands of the farmer is improved; nearly two-thirds of this

land nominally in farms has not yet been called on to produce food. There are swamps to be drained, cut-over forests to be cleared, deserts to be watered, and dry lands to be made productive by specialized crops and methods. Without increasing the efficiency of its improved acres, the nation still possesses enough resources in terms of land alone to feed double the population that exists to-day. It has been the author's endeavor to chart this empire of opportunity that awaits the gleaner in the period of reclamation which is now setting toward flood tide.

The problem of the fertility of the soil is one of national importance; it determines not only the fortunes of the farmer in the field, but, in the end, the life of the nation. For generations past, agricultural literature has been buried under a theory of doom imposed by a great chemist, Liebig, which teaches that the resources of the soil are as definite as cash in a bank or coal in a mine. Under this orthodox theory which actuates the machinery of the greater part of agricultural education as it exists to-day, the farmer must feed the soil if he would have the soil continue to feed him. Failing this, it has been variously computed that

our soils, cropped for a scant three generations, contain only enough mineral elements to continue producing food for seventy-five, one hundred, or one hundred and fifty years. The sole means offered to forestall this inevitable day of doom is the use of chemicals as fertilizers, limited in supply themselves; a system which carried to its logical conclusion considers the soil merely as a mixing bowl in which food may be manufactured synthetically.

Recently, however, there has been put forward a more logical and less pessimistic hypothesis concerning the fertility of the soil—a hypothesis fathered by the scientists composing the federal Bureau of Soils at Washington and backed by a long series of classic experiments, as well as by the teachings of history. This theory assumes the mineral elements of the soil to be inexhaustible, an assumption which the history of China, whose soils are unimpaired, indeed are the richest in the world after 4,000 years of intensive cultivation, seems to justify.

An examination of this new hypothesis, in the light of orthodox criticism, shares the pages with a consideration of the extent of our land resources.

CONTENTS

CHAPTER		PAGE
I.	The Farmer of Yesterday	1
II.	The Line of Least Resistance . . .	34
III.	The Gleaners	68
IV.	The Dry Lands and the Forests . .	98
V.	The Division of Soils and the Specialization of Crops	141
VI.	The Bookkeeping Theory of Soil Fertility	173
VII.	The Soil as an Immutable Asset . .	212
VIII.	The Evidence of History and Research	243
IX.	Soil Sanitation	272
	Conclusion	300

THE FARMER OF TO-MORROW

"The soil is the one indestructible, immutable asset that the Nation possesses. It is the one resource that cannot be exhausted; that cannot be used up. It may be impaired by abuse, but never destroyed."

MILTON WHITNEY.

FARMER OF TO-MORROW

CHAPTER I

THE FARMER OF YESTERDAY

JAMES FENIMORE COOPER, writing in 1827, marveled that in his own lifetime he had seen frontiersmen, lovers of the wild, driven from the forests of the upper Hudson across the prairies of the Middle West, finally to take refuge amid the arid plateaus and mountain wildernesses of the Great American Desert, before the advancing tide of settlements. The backwoodsmen of Kentucky and Tennessee had begun to move on into the unknown regions beyond the Mississippi as early as 1804, almost before the actual transfer of the territory of Louisiana had become a fact. Lewis and Clark, in their historic march from St. Louis to the mouth of the Columbia River, begun in 1804, found white men before

them, mostly Canadian French, light-hearted, care-free wanderers who had come in from Montreal through the Straits of Mackinac at the confluence of Lake Michigan and Lake Huron and established a well-defined route of travel to the plains beyond the Mississippi by way of Green Bay and the Fox and Wisconsin Rivers.

Still, as late as 1832, Washington Irving, journeying up the Missouri and out across the plains in search of information as to the "far west" at first-hand, conceived the "Great American Desert" as a territory so remote, so mythical in its confines and so terrible in its hardships that he believed it would never become an integral part of the States. Instead, he pictured fantastically the growth there of another nation, a nation that would forever exist beyond the pale of civilization, a nation composed of outcasts, half-breeds, the scum of society; a race of men so wild, so lawless, so adventurous that they had already adopted the worst traits of the savage Indians as their own and become the blood-brothers of the red-men of the plains.

He pictured this roving mongrel horde pushed farther and farther back by the exten-

sion of settlements of law and order, until finally they would be forced to bond together for self-protection in the heart of the desert; and from them in time would spring an entity with traditions and ethics founded on barbarism and outlawry. Yet he himself lived to see "the Great American Desert" as a name wiped out of memory, and law and order established in the Great Plains region which once he had confidently predicted would never yield to the plow.

The Oregon Trail had already become a fact in 1846, and a year or two later saw Mormon regiments that had fought in the Mexican War moving slowly across the plains and over the mountain barrier with their families and cattle, to be mustered out in California. In another year came the rush of gold-seekers, and before another decade had elapsed the country west of the Mississippi had become sufficiently populous to be rent asunder by the political question of States' rights. Cooper, the novelist, writing again in 1847, pointed with pride to the million and one-half souls which constituted the population of the State of New York, yet he ventured the prediction that the agricultural re-

sources of that State were so vast as to feed its people "for ages to come."

These recorded facts relate, we might almost say, to contemporary history, the history of to-day. In 1909 there were still 395 widows of the War of 1812 on the pension roll of the government, and 2,459 soldiers of the war with Mexico still survived. It was only yesterday that our grandfathers went "west" with their yokes of oxen and iron kettles, considering themselves very well outfitted indeed; and selected fertile river bottoms where the most desultory cultivation removed them from want.

Following the Civil War came the Homestead Act, and out across the prairies swept the disbanded armies checking off the sections square by square; moving like a cloud of wild pigeons, platoons from the rear-guard constantly detaching themselves and taking their place at the head of the ever-advancing column.

Land, land, the illimitable land, the magic carpet with a rainbow at one end!

Then came the period of the late 'eighties, the period of over-colonization, overproduction—too much land, too much food, an

economic crisis quite as catastrophic in its way as famine. There was no one so poor as the farmer, nothing so cheap as corn, except hogs on the hoof, and grain became fuel. In the few decades following the Civil War, agriculture had emerged from its pastoral stage wherein each community had been sufficient unto itself. A contagion of railroad building cut up the prairies, bringing world markets, exchange, and perplexing wants into a region which heretofore had been its own butcher, baker and candle-stick maker. This period of too much land, too much food, and over-development in transportation that glutted the world market, brought about a decline in values which did not reach its low ebb until as late as 1896. In this connection it is worthy of note that, when a British railroad commission recently reported to its government on American Railroading, it explained the efficiency of our railroads as being due to the penny-pinching attention to details which grew out of receiverships. Practically all our great railroad systems of the present day are the reconstruction of the bankruptcies of the late 'eighties and early 'nineties.

It was then that our Jeremiahs, relics of a

pastoral period, *came back from the land.* The period is within the memory of the rising generation when the tide turned toward the cities; when nothing was so cheap as land, and whole townships were abandoned to mortgages that could not be satisfied. Jeremiah the Reaper, who had gone forth seeking a "homestead," saw a miserable old age, and his sons mounted high stools and adjusted high-power spectacles and became bookkeepers. It was much better to buy two-cent hogs than to sell them.

All of which brings us to our Jeremiah of the present day, who wants to go back *to* the land.

* * * * * * * *

This Jeremiah of to-day is a strange product. He is a fact, yet he is a glaring fallacy. He is a son of the Land, a son of sons of generations of the Land; yet in the one or two decades that have passed since he turned his back on the Land, too much Land, Land as a curse, he has involved himself and his fellows in a situation of such complexity that two out of every three hours he toils for his bread are devoted to the intricate process of bringing to his own door that same bread, the

product of the Land, without which he must die. It has not yet occurred to him in the mass that he has developed concentration and congestion to a point so remote from the pastoral ideal of his forefathers that he has created the greatest anomaly of Waste in history, a condition in which the simple act of distribution of food has become infinitely more complex than the basic process of production itself.

He has built cities—228 of which boast over 25,000 population; 50 more than 100,000; 19 more than a quarter of a million; 5 more than half a million, and 3 from 1,500,000 to 5,000,000. He has constructed steel mills (a single corporation employing more than 200,000 souls), not only to transport the surplus of food, clothing and luxuries to world markets, but to feed, clothe and amuse himself in the very act of doing it. He has devised a system of banking and exchange as clumsy and timid as a rabbit, to move crops. He has acquired steamships, canals, telephones and telegraphs, marvelous systems of intercommunication, capitalized at ten times the value of the nation's farm lands that he knew a generation ago—capitalized at stupendous figures not

only in response to the demands of general manufactures, but also because he has chosen to turn his back on Land, and created the necessity of delivering his food from his hand to his mouth. Around him are clerks, stenographers, merchants to administer to his needs, carpenters, masons, plumbers, artisans of hundreds of specialized trades, lawyers, doctors, ministers for his material and spiritual needs, and actors, musicians and buffoons to make him happy, merely for the purpose of permitting him to toil that he may live.

It would be an interesting task to determine (or to attempt to determine, for the task would be difficult) how great a percentage of the population of five million souls who constitute the city of New York have their entire time employed in the process of feeding their fellows—who, by their efforts, produce nothing but the means of transporting food to satisfy their own hunger—who elect to devote their lives to the task of moving food from the spot where it is produced in abundance to the spot where it is not produced at all. It is a far cry indeed from the Jeremiah of to-day to the simple pastoral self-sufficiency of his ancestors. Yet the population of the cities is be-

ing recruited in increasing numbers from the farms. It is too late to turn back the hands of the clock, though we still persist in the fiction that we are an agricultural nation.

Look at Jeremiah for a moment. He is, say, thirty-five, and lives in a flat. He works eight hours, sleeps nine, and spends the remainder of his day in his carpet slippers and street cars.

Light, air, fuel and water, the products of Nature, are fed to him through tubes; vacuum and gravity are harnessed for his light housekeeping. The municipality, of which he is a member in good standing, disposes of his waste paper and potato peelings; regulates noise and smell; inspects his food; guarantees him so many cubic feet of air to sleep in, a minimum bacterial count of 50,000 to the c. c. in his morning's milk, and a ladder in case of fire; assumes the supervision of the eyes, teeth and intellect of his children; polices him, sweeps his streets, counts him at birth, marriage and death and at the polls, fumigates him, makes music for him in the parks, and keeps him off the grass.

All that is left for Jeremiah is to work eight hours a day and keep on good terms with his

janitor. And a paternal automatism extracts its tithes by a process at once so complex and so lulling that it borders on the mystic. He is not even enumerated as a "tax-payer." He buys bread by the pound, potatoes by the quart and eggs by the ounce, and milk, signed, sealed and delivered in glass. Every time he expends one dollar for food, thirty-five cents of it is edible, and sixty-five cents goes for wrapping paper and string, interstate commerce, and demurrage. Jeremiah is a consumer.

But Jeremiah dreams of the days of his youth: of the wood pile, the evening chores, the frozen pump, apples that have never known a feather-duster, and the great shadowy barn with its fragrant haymow and its row of soft-eyed placid cows. Jeremiah and Mary —they met and married in a boarding house —take the subway to Van Cortlandt Park or the ferry boat to Staten Island every Sunday to walk on the grass. The lure of the land is in their souls, and they wear rubber heels on their shoes.

A remote, an almost hypothetical aunt names them in her will. This opens a door—because in all his years of toil he has been spending so much in bringing his food from

the farm that he has never been able to save enough to go back to the farm where the food comes from. Jeremiah resigns his high stool, his high-power spectacles and his green shade, and a through Pullman sets Jeremiah and Mary down on a willow-bank, where he was born and raised.

Let us say that this was in Iowa, because Iowa as a State presents in a mass the conditions developed in our national life in that brief interval between the time when Jeremiah turned his back on the Land, and to-day, when he seeks to return.

Yes, this is home. But somehow things do not look the same. There is an extra wing on the house and a second story has been added; it is freshly painted and shingled and wears green blinds. There is a red barn with white battens, housing a glistening gang plow and a binder, and a pair of ton horses with big creases in their backs are browsing in the feed lot. There is a wind-mill and a telephone, and hot-and-cold water, and woven wire fences, and a suspicious odor of gasoline.

"Here is the screw loose," thought Jeremiah. "The farmer is making too much

money. There are too many consumers and not enough producers. The farmer has got hold of the gate receipts. I am glad I came."

"Well, well," laughed the willow-bank farmer as he looked Jerry over, "I remember you as a little shaver. I bought this farm from your father at ten dollars an acre. I tried to worm out of the deal but the old man held me to it."

"I was born here," said Jeremiah, gazing sentimentally at the willow-bank—it did look like home, after all. "I should like to buy the farm back if it is for sale."

Yes, this was the very quarter-section that Jeremiah's grandfather drew out of the grab-bag, back in the 'forties, when the West was a magic carpet with a rainbow at one end, when one had to hunt over five square miles in this neighborhood to find a whole person, excluding Indians not taxed. Yes, this was the very spot where the old gentleman cultivated hogs with long legs as beasts of burden to carry hams and bacon to market. (Later, when railways came, they bred the legs down to nubbins, for delicatessen.) Yes, this was the very spot where less than thirty years ago Jeremiah's father fed his corn to the stove,

because there was too much corn and too many hogs, and not enough people in the whole world to eat the hogs; when there was nobody so poor as the farmer.

And, standing before him now, was the very man who had gone down in the traditions of the family as having been hooked and landed by the second generation of Jeremiahs at *ten dollars an acre.* The memory of that ten dollars had bathed the declining days of the second generation in sunshine.

And here was the third generation, looking wistfully at the fat fields crowding the fence posts, wondering what had become of the swamp, the wood lot, the hog-wallow, and the mud road.

"Ten dollars an acre!" Jeremiah was musing to himself. He was dreaming of the magic carpet with a——

And the willow-bank farmer . . . What was he dreaming about? He was dreaming of Saskatchewan. He was anxious to scamper across the map with his three stalwart sons to the last tee. He liked the looks of this sentimental young couple. He would do his best to arrange matters for them.

Not on the basis of corn as fuel, however.

He was figuring on dollar wheat, sixty-cent corn, and ten-cent hogs.

All his land nominally in farm was real farm. It was mellow prairie loam, the mold of centuries, from fifteen to one hundred feet deep. It was rich, and ripe for skinning—one hundred acres of it.

The average farmer ought to consider his plant above the average of his State. But the willow-bank farmer would figure himself below. He would even throw off seven dollars and forty-four cents and four mills—and call it an even fifteen thousand dollars.

One hundred and fifty dollars an acre!

Jeremiah untied his livery horse and assisted Mary to her seat, and they drove slowly back to town, leaving the willow-bank farmer tinkering over a new gasoline thrashing outfit. They remembered having read somewhere that Dean Liberty H. Bailey, of the lamented Country Life Commission, had said that the back-to-the-land movement was an economic fallacy. But they remembered this only for the moment. Economic fallacies have to do with masses, not individuals. If the willow-bank farmer could buy automobiles and wear green shutters on his house, Jeremiah and

Mary could do likewise with the same tools. So they drove back to the farm the next day.

The willow-bank farmer was inclined to be generous. He accepted a payment of two thousand dollars cash (which had been earning six per cent. in an industrial investment); and he accepted a mortgage of thirteen thousand dollars at six per cent.

In other words, Jeremiah and Mary were to pay nine dollars an acre rent. Land is capital! That was reasonable and business-like. Jeremiah and Mary were going into the *business* of manufacturing food.

And the farmer, rather than put the sentimental young couple to the expense of buying machinery, rented them his. He did not know much about such transactions; but Jeremiah, having been a bookkeeper in his rôle of consumer, knew all about it. He suggested ten per cent. for depreciation, and six per cent. interest. A farmer, or a manufacturer, replaces his machinery every ten years, on the average; and this seemed equitable. No industrial concern could pay a dividend and keep out of the hands of the postal authorities without debiting a like charge to equipment.

So much for his plant and equipment. Now for the item of labor.

Jeremiah didn't have any sons of his own. He couldn't pay his labor in board and clothing and salt. He had to hire labor. Twenty cents an hour for human labor, and ten cents an hour for horses—including care and keep.

And he concluded that if hired labor was worth twenty cents an hour, his own labor was worth twenty cents an hour.

And he concluded that if a scrubwoman was worth five cents an hour, Mary was worth five cents an hour. Mary cooked and washed and ironed and sewed and darned and swept and dusted and made the beds and looked after the chickens and nursed the garden and churned butter and set the milk. She was labor.

He concluded, furthermore, that there were profits—or recompense, at least—due to himself as the superintendent who managed and risked so much capital.

In addition, there were the taxes and insurance—say three per cent. on a three-fifths valuation.

Jeremiah, you see, was entering the *business*

of farming. He was a bookkeeper and he knew all about costs of production.

Jeremiah is the new pioneer. Cheap land, free land, is gone. When there is no more land to give away, land becomes capital, exacts rent. No matter whether the price is too high or too low, it is fixed by culture and sentiment and speculation; by three generations of homesteading, and by a population that has increased fourfold in seventy years.

Are Jeremiah's fixed charges, his cost of production, too high? Ask yourself, Mr. Farmer, you of the Middle West, of the Rain Belt, you who are producing the surplus for hungry mouths. You say that your land—which may happen to be in the door-yard of the Grain Pit and the Stock Yards—is worth more than one hundred and fifty dollars an acre. You say that your neighbor's land, land in the next county, in the next State, is worth less than one hundred and fifty dollars. If your acre does not exact the same rent as Jeremiah's then the process of distribution makes up the difference.

What does your labor cost you? How much does it cost you to grow an acre of corn? You don't know! Hired labor, paid for by the

hour, day, week, or month, was beyond the experience of fifty-two per cent. of the Iowa farmers canvassed by the 1910 census. Forty-eight per cent. of them reported expenditures for labor at one time or another. They knew how much hired labor cost them. But how much their own labor cost, how much it was worth, they did not know. And the Census Bureau did not think it worth while to inquire.

Several years ago experts of the Department of Agriculture picked out five thousand wide-awake farmers all over the country and asked them to coöperate with the department in running down the question of labor. How much did it cost them, in time or wages, to grow an acre of corn, labor to be charged at prevailing rates?

In New England an acre of corn cost $16.82, not counting "rent"; in the South Atlantic States, $11.29; in the Middle West, from $9.10 to $6.82.

The willow-bank farmer kindly advised Jeremiah as to crops. Had he not been farming these acres for more than a score of years? Jeremiah took his advice. Thus custom and habit determine crops.

He sowed his seed and prayed for rain. The rest was up to the Weather Man.

Jupiter Pluvius, the arch-manufacturer of aridity and humidity, is the court of last resort. If the heavens are propitious, fat crops; if the heavens turn a cold, sour face to the land, lean crops. Sunshine and rain, fair and foul weather, text-books to the contrary notwithstanding, have been the sole factor affecting the yield of our acres since the American farmer was in his swaddling-clothes. Weather is the pressure gauge; it determines the revolutions per minute, so to speak, of this big machine. If our acres are not producing enough food, put more acres under cultivation.

We are producing three times as much corn to-day as we did fifty years ago, not because we have increased the efficiency of our plant, but merely because we are plowing three times as many acres.

Several years ago two weather-wise experts (J. Warren Smith, Section Director of the Weather Bureau at Washington, and Professor W. D. Gibbs, of the New Hampshire State College) constructed two charts to show the relation between crops and weather. One chart was to illustrate the rainfall in inches;

the other to illustrate the yield per acre, bushels of corn, in the corn-growing states. They fitted the two charts together. Even the two experts were not prepared for the striking result shown. The two charts fitted each other like a dovetail joint! Every variation in rainfall was accompanied by a corresponding variation in bushels of corn.

In as recent a period of enlightenment as 1901 there was a famine in corn. Solely for the reason that Jupiter Pluvius loafed on his job. He had been expected to produce eleven inches of rain that summer, and he actually furnished only a scant six inches. Don't blame the farmer. Blame the Weather Man.

Take another instance: During the decade 1867-1876, the best yield of corn in Nebraska was 42.2 bushels to the acre—in 1869, and the poorest yield was 10 bushels to the acre—in 1874. The ten-year average was 32.5. Somewhere between high and low a whole season's product was lost. Was it the farmer's fault that he received one bushel of corn one year for the same amount of labor that paid him four bushels another year?

Human ingenuity has constructed intricate machinery to crop ten acres with the ease of

one. Machinery expands acreage. It does not increase productivity. The only additional labor Jeremiah expends to-day over what his grandfather expended is in fighting weeds, insects, and fungous diseases. These three scourges of elementary agriculture were driven from their happy hunting-grounds by the plow, and they have turned on their despoiler, subdivided their species into highly specialized organizations, and are thriving on civilized fare.

So Jeremiah is farming at the same rate to-day that he was fifty years ago—one hundred years ago. In fact, he is farming at the same rate as the sixteenth-century yokel who plowed with a crooked stick instead of a gasoline tractor. This is amply proved by many records. The burghers of Schmatzfeld, Germany, produced an average of 12.5 bushels of wheat to the acre in the period from 1552 to 1557. Minnesota, a State which grows more wheat than the entire country east of the Alleghanies and south of the Ohio River, has averaged 12.4 bushels for fifty years.

The Weather Man has been dodging jokes patiently for more than forty years, amassing enough evidence to take the responsibility. He

has found that sunshine and rain vary not only from year to year, but from decade to decade; that weather travels in great cycles. Apparently we have passed through one complete cycle.

A few years after Civil War, the yield of our acres began to decline. The land wasn't "exhausted." Most of it was new land that had never known the plow. And the slump was characteristic of all sections, from seaboard to seaboard. Then, in the middle 'eighties, the line began to recover itself. (It is worth while noting in passing that it was during the decade of lowest yields that the country passed through its most critical economic period, a period of vast overproduction of foodstuffs. That was the period of *too much land* for the given rate of speed, the sunshine-and-rain rate of speed.) The line ascends slowly for another ten years. In another twenty it has recovered itself, and Jeremiah is getting as much out of an acre in bushels as his Civil War competitor did. It is still on the upward wave.

And so Jeremiah plants his corn and prays for rain. If he follows the methods of his neighbors, he will plant five acres out of every

fourteen in corn; and two in oats, and two in hay to feed the horses that cultivate the corn. Thus nine out of fourteen acres go for corn, directly or indirectly.

Jeremiah has a good year, an average year. Sunshine and rain are kind to him. Bugs and blight are kept at a respectful distance. His corn is worth fourteen dollars an acre.

The average, in his neighborhood, has been $11.54 since the time when the first cultivated hog was dressed for market. Five staple crops in his neighborhood average less than fourteen dollars. The ten staple crops of the United States that account for ninety-five per cent. of the three hundred and ten million acres which the farmer actually plows (wheat, corn, oats, barley, rye, buckwheat, potatoes, tobacco, hay, and cotton) have varied from $16.42 in 1909 (when the cost of living became academic) to $7.94 in 1896. The average acreage return has been $12.04 since the dawn of statistics, forty-five years ago. That means the cultivated acre, not the scrub one.

So you see Jeremiah is rather successful, in spite of his years as a consumer.

Jeremiah opens his books and strikes a balance—in red ink!

He looks once, he looks twice, he dashes across the pasture lot to Neighbor Jones, who is polishing off a new automobile in the sunshine. Jeremiah explodes with the direful tidings.

He is bankrupt! Farmer Jones is bankrupt! Everybody is bankrupt! They ought to be in the hands of a conservator, or at least a receiver. And Farmer Jones—who has been there a long time—looks at Jeremiah, once, twice, and then says *honk! honk!* with his new horn.

But there it is in black and white. Look back a few paragraphs and figure it out for yourself, in rent, labor, and taxes. Never mind the salary for the superintendent who was to risk and manage so much capital. Cut out the five cents an hour that was to go to Mary. In bare time it has cost Jeremiah from seven to nine dollars an acre to sow, cultivate, harvest, and haul his corn. Add the item of interest. Then bring on the tax bills. Jeremiah sells his corn at the market, the price of hunger, the price with which his neighbors buy automobiles. And for every acre of food he has manufactured, he stands an actual loss.

If he doesn't pay rent—that is, interest on

capital—the sheriff will get him. If he doesn't pay his labor, his men will garnishee him. If he doesn't pay his taxes, he will be advertised. The only privilege land has given him is to expend his labor. The only privilege labor has given him is to draw on his bank account.

"And you are in the same boat that I am!" cried Jeremiah to Farmer Jones.

"Wait a minute," says Neighbor Jones. "Why should I pay interest—or rent, as you call it—on my land? It didn't cost me one hundred and fifty dollars an acre. I inherited it from my father. The Government caught him when he wasn't looking and made him a present of it. And what have wages got to do with me?" asks Farmer Jones. "I have two sons and a daughter and wife. I pay them their salt. And we have just bought a new six-cylinder sixty."

"Isn't your time worth anything?" asked Jeremiah.

"It's my own time, isn't it?" demanded Farmer Jones. "I can do what I please with it."

"If you sold your land and invested the cash in a factory to make biscuits or buttons

or gunpowder, instead of keeping it invested in land to grow corn, would you expect it to return you anything? Or would you consider that it merely provided you with a job that you could pass around among all the members of your family?"

"I would expect it to return me something, of course," admitted Farmer Jones.

"Say you invested it in industrial stock," suggested Jeremiah. "You would not have to turn a hand for that six per cent., would you? You and your family could ride around in your six-cylinder sixty all day, and you wouldn't have to bother about getting up at four o'clock in the morning to feed the horses and start for the field. Your capital would work for you. And, Mr. Jones," went on the bankrupt, "if you had inherited a soap factory instead of a farm from your father, that soap factory would have to earn interest on its capital, and pay fixed charges, to stay in business, wouldn't it? Or would you run it as a charitable institution and forget to figure on cost of production? How long do you think your laborers would work for you if you paid them salt and garden truck and a fresh chicken on Sunday? And how did you hap-

pen to sell your corn at forty cents a bushel, Mr. Jones?"

"That's the market price," explained Mr. Jones. "That's what they are paying."

"Exactly! That's what *they* offered you, If you were making soap instead of corn, do you think you would sell your soap for what *they* offered you? Or do you think you would sell it for what it cost to manufacture, plus a fair interest on the capital involved?"

But Farmer Jones isn't bothering about abstruse problems. He isn't bothering about the cost of production. He is interested only in the credit side of the ledger. The debits don't affect him. If it really is true that he has to pay rent and wages, then his liabilities are in the hands of preferred creditors, himself and his wife, and their sons and daughters. What is a small matter of insolvency, if one can keep it in the family circle? If Farmer Jones is broke because he owes himself money, you will have to show him.

"But how about me!" cried Jeremiah. "I think I see the sheriff coming down the road now."

It wasn't the sheriff. It was only the willow-bank farmer coming back from Canada

and anxious to do business at the old stand. He was willing to wipe the slate clean, in consideration of the fact that there is no place like home, after all. When he heard Jeremiah's story, the willow-bank farmer had the same notions as Farmer Jones; but he assumed a little more sympathy for Jeremiah.

"Why don't you go on farther west, where you can get land for fifty or one hundred dollars an acre?" he asked.

"What good would that do me?" asked Jeremiah. "What I would save in interest on capital, I would lose in freight getting my corn to market. It would be all the same in the long run."

And he was right. Corn in Kansas is worth about three dollars an acre less than corn in Iowa.

Something is wrong.

You will probably say at this point that the remedy is obvious. Let Jeremiah put on more steam. He is running his plant at one-third pressure, you say. The American farmer is growing only twenty-seven bushels of corn to the acre. Why, in 1910, a school-boy, Jerry Moore, harvested two hundred and twenty-seven and two-thirds bushels of corn on a

measured acre! That shows what could be done if the American farmer would increase his speed.

Let us apply this remedy to Jeremiah as an individual. In the first place, it cost little Jerry Moore something like one hundred and forty dollars in capital and labor to win his medal in the Boys' Corn Growing Contest. That contest was a brilliant example of how to farm with capital. Jeremiah doesn't want to be told how to farm *with capital.* He wants to know how to farm *without capital.* He hasn't one hundred and forty dollars, nor half of it, nor yet a quarter of it, to expend on a single acre. The world isn't hungry enough yet to finance him. Little Belgium is, with its six hundred and fifty souls to the square mile; but the United States, with only thirty-one souls to the square mile, is still remote from the necessity.

Now apply the remedy to Jeremiah as a mass, to the great American farmer. How would it work out? Take Iowa as an example. She is a good example because she grows thirty times as much corn as the entire western half of the country.

In her bumper year (1910) she grew three

hundred and forty million bushels. The price fell to thirty-eight cents.

The next year she grew two hundred and seventy million. The price rose to fifty-five cents.

If she grew five hundred millions—as she could—the price would go to twenty cents, on the same basis of calculating.

Fifty-five-cent corn paid the farmers $148,000,000.

Thirty-eight-cent corn paid them $129,000,000.

Twenty-cent corn would pay them $100,000,000!

And, the freight on twenty-cent corn is the same as the freight on dollar corn. No, the so-called *intelligent culture* is no more use to Jeremiah than his boot-straps would be to pull him out of the mire. Until the world is hungry enough to finance Jeremiah; or until the middle-men give him more than thirty-five cents of the consumer's dollar, text-book farming will remain a dogma and nothing more.

A thousand, or a hundred thousand, farmers may dabble in it, providing they have enough capital—because this efficiency engineering

costs money; but they must be very careful or they will upset the balance. The margin is slight. A few years ago potato growers in Maine became so efficient, so intelligent, that they were forced to sell out at eleven cents a bushel.

"If the farmers of the United States were to produce as much, acre for acre, to-day, as the farmers of Belgium," said Professor Milton Whitney, of the Bureau of Soils, recently, "the world would face the greatest panic in its history."

Then what is wrong with Jeremiah?

Is the price of land too high?

Is the price of food too low?

The trouble with Jeremiah is that he is ahead of his times. He came too late for the old order of things. He is too early for the new order.

Jeremiah tried to compete free-handed, on improved acres, with a subsidized industry—with an industry that has grown up to a capitalization of *fifty billion dollars,* and hasn't found its feet yet.

Seventy per cent. of his six and a half million competitors can afford to ignore land as representing capital. They got it for nothing

or for a song. Till to-day—or let us say yesterday—a charitable old gentleman in chin whiskers and a red-white-and-blue waistcoat has been lying awake nights devising new schemes for giving away quarter-sections. Now farm land is all gone, except for the small matter of, say, two hundred and sixty million acres of scenery that nobody would take as a gift. It was all gone ten years ago, except for a core, a scant four per cent. The latecomers lined up and drew lots for this four per cent. Our farm land has been employed till to-day—or yesterday—not as capital, but as a means of labor. And as labor it has paid big wages. It didn't have to pay interest on capital until there was no more of it to be had for the asking.

Meantime, "unearned increment" has suddenly appeared on the horizon. Railroads, cities, the increasing hunger of the world, and the demands of those who drew blanks in the lottery, have increased the appraised price of land as capital 118 per cent. in the first ten years of the new century.

With capital comes interest, rent. Jeremiah is the pioneer of the *business* of farming, the establishment of agriculture on its

permanent basis. He can't compete with the old order yet.

Then the price of land is too high!

Possibly. But if you speak softly, no one will suspect it—except the Jeremiahs—because seventy per cent. of the farms are still being worked as a means of labor, according to the moon. You can't persuade this seventy per cent. that cost of production means anything to them, when they happen to be both delinquent debtor and amiable creditor rolled into one.

CHAPTER II

THE LINE OF LEAST RESISTANCE

The actual task of gathering up our belongings and starting "back to the land" is so much more of an undertaking than the mere talking about it, that the so-called movement has never gone much beyond breakfast-table conversation. We began talking about it a decade or two ago when we were still pastoral enough as a nation to count two-thirds of the population as rural. To-day nearly one-half of our ninety-two millions elect to live in cities, places remote from the food surplus—actually forty-six per cent. in the last census. So the pendulum has swung in the other direction and is still swinging.

Occasionally, however, an individual does break away, with a vague idea of following in the foot-steps of his grandfather—or maybe his father—who went "west" with a yoke of oxen and an iron kettle. Such a one, for instance,

we find seeking advice in the questions-and-answers column of a middle-west farm weekly. He has a capital of five thousand dollars and he would like to know what section of the country offers him the best advantages for farming. This editor—this is an actual instance—replied:

"If you have no more than five thousand dollars I would not advise you to attempt farming."

Note, the editor did not ask the correspondent to state what his training and experience had been—if, in other words, he possessed the qualifications to fit him for the business he purposed to enter. Instead, he dismissed the inquirer—who probably represents a million of his kind—as he would dismiss a mechanic too poor to buy tools.

There is a tremendous gap (not so much one of years as of rapidly changing conditions) between the viewpoint of this practical and experienced observer of latter-day conditions and that of Horace Greeley less than two generations ago.

It is the difference between land which has, in an incredibly short time, become capital, demanding its tithe—and land as we knew it

in the days of our youth, too much land, nothing but land, land as means of labor. The fact that the average farm in the State of Iowa was appraised at over fifteen thousand dollars in value by the census enumerators of 1910 is sufficient to open our eyes to the developments of the last decade.

We are already beginning to appreciate the fact—though the time is not yet sufficiently remote to give us the proper perspective—that the opening of the present century marks a very definite milestone in the progress of the nation. The period is so definite in fact that its characteristics can be reduced to a simple chart. On the one side, the closing decades of the nineteenth century is a slowly descending line, picturing the declining fortunes of the United States as an agricultural nation, due to over-development of land resources. On the other side is a steadily ascending line, marking the sudden rise of manufactures and commerce, a new alignment of producers and consumers of food, eventually bringing about a new era of prosperity in the despised industry of farming. Trace the history of great individual fortunes founded on commerce and manufactures and

we find that practically all of them came into existence with the beginning of the twentieth century. At the same time the class of immigrants from Europe began to change. They were no longer tillers of the soil. They were cheap labor, drafted by expanding manufacturing industries. During the decade closing the last century we welcomed three million souls, mostly immigrants from the south of Europe. During the first decade of the present century we tripled the number.

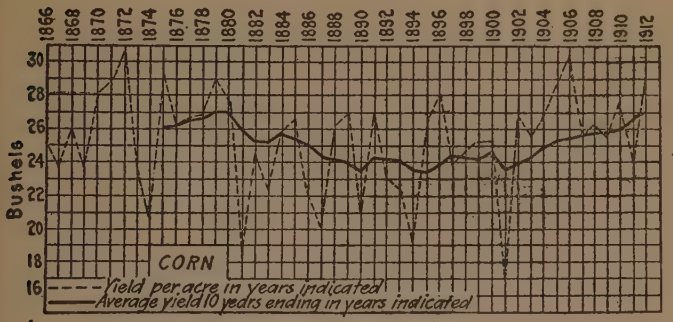
This abrupt change in the character of the national life must have reacted on the basic industry—that of supplying food for hungry mouths. That is the phase of the situation with which we have to do here. It is responsible for the new problems that face our Jeremiahs, who are beginning to turn their faces toward the land.

Farming in any country must first pass through its pastoral stage, the stage when each unit is sufficient unto itself. But sooner or later it develops into an industry having a surplus to exchange, an industry which must be conducted according to business principles. Each farm eventually becomes a *producing plant,* subject to the same requirements as the

business of making buttons or biscuits. If the correspondent who toiled and saved for years to fit himself to go back to the land had been a close observer of present-day conditions, he would have found an explanation of the editor's contempt for his five thousand dollars capital in a single fact gleaned from the last census. In the decade ending in April, 1910, the population of the United States—mouths to be fed—increased twenty-one per cent; in the same period, land—the source of food—increased in acreage only 4.8 per cent. That means that every acre nominally in farms was called on to feed more mouths than before.

Yet the average acre did not materially increase in productiveness in those ten years. In spite of the propaganda of intensive farming, which is to make two blades of grass grow where one grew before, the productiveness of our manufacturing plant for food has not varied in efficiency since the beginning. It has followed absolutely the pressure gage imposed by fluctuating weather conditions. To meet the additional demands of hunger, the industry of farming has heretofore increased its floor space, the number of acres under the plow. This is what it attempted to do at the begin-

ning of the present century. But instead of increasing its floor space twenty-one per cent., it increased it less than one-fourth of that amount. There seemed only one way to make up for the deficiency. That was to turn to



[1] *From United States Crop Reporter, February, 1913.*

The weighted acreage yield of corn for the country as a whole. Note the dip marking the middle period, due to weather cycles. All crops in all sections of the country exhibit the same general tendency, i. e., low yields during the 'eighties and 'nineties. The fact that this period of lowest production was also a period of lowest prices illustrates the extent of the over-development of our food resources at that time.

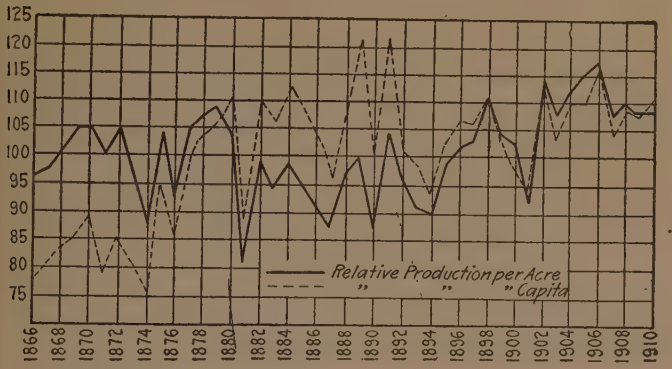
the exports of food-stuffs which have been responsible for the traditional balance of trade in our favor. We had to retain at home the food we had formerly shipped abroad. In the last half of the last decade the exports of food-stuffs began a rapid decline.

Two things were bound to happen. First,

the price of food was bound to go up. Second, the price of land as capital—land as the plant in which is manufactured a limited supply of food—must follow suit. That is why the correspondent whose father went west with a yoke of oxen and an iron kettle found the editor rather impatient at his mention of five thousand dollars to outfit a modern farmer with land, stock and machinery.

There is not much margin between famine and plenty. The world's hunger follows close on the heels of harvest. A reader of statistical bent can trace the history of the American farmer, explain all his ups and downs, by examining the per capita production of bread and meat since the Civil War. A chart comprised of these elements would show that the farmer was prosperous during the decade following the Civil War, in spite of depreciated currency and reconstruction. There were too many mouths to feed and not enough acres under cultivation to feed them. Then came the Homestead Act, with its tide of settlers rolling west, finally to be turned back by the wall of mountains. By 1879 we find the "floor space" devoted to producing food catching up with the normal demands of an increasing

population; and from 1879 onward until 1896 (the year of the lowest food prices in the entire cycle) the farmers of the west carried over-



U. S. Crop Reporter, Dec. 1911.

Chart showing relative production per acre and per capita in the United States of 10 crops (wheat, corn, oats, barley, buckwheat, rye, potatoes, hay, tobacco, and cotton) combined. 100 represents the average for the 43 years, 1833-1908.

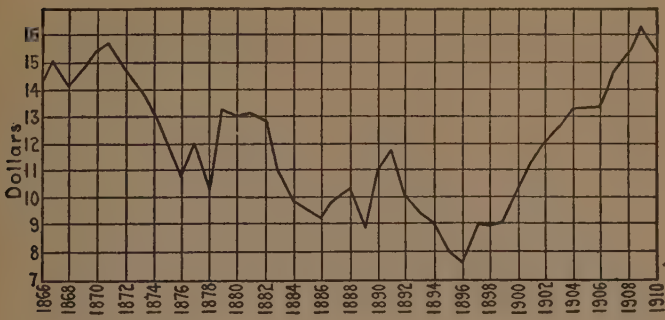
production to a point where even the world market could not absorb the surplus. It was during this period that old Jeremiah, the pioneer, came *back from the land* because there was no one so poor as the farmer. It was during the later part of this same period that our present-day trans-continental trunk-lines were reconstructed out of the receiverships following two decades of depression. In the latter part of the 'nineties hunger again caught up.

with the plow, passed it with the opening of the new century, and since then has maintained the lead.

A business which produces too little or too much draws its returns accordingly. Every item in lack of balance, on one side or the other of the scale, is reflected in dollars and cents. The dollars and cents return to the American farmer for the last fifty years is in fact a huge curve, touching low ebb at the middle period. Thus the farmer who stayed in business in the unsettled times following the Civil War received $15.74 for every acre of floor space he devoted to the production of food in 1871. But his returns began to fall away with the rush of homesteaders—competitors. A line indicating value per acre of farm products tells the story of the decline in fortune of the farmer of those days. It is a ragged line, because in some years the heavens smiled bountifully on the land, doubling its superabundance; while other years swung the balance in the opposite direction, either because of drought or too much rain. Nevertheless the returns the farmer gleaned from his acres fell steadily.

In 1886 he had to be content with a return

of only $9.41 for the labor he expended on one acre. It cost him just as much care and



U. S. Crop Reporter, Dec. 1911.

Chart showing value of the production of 1 acre (wheat, corn, oats, barley, rye, buckwheat, potatoes, tobacco, hay and cotton) combined, for 95 per cent. of area of full crops.

Yearly value per acre of 10 crops combined.

1910	$15.49	1887	$10.14
1909	16.42	1886	9.41
1908	15.32	1885	9.72
1907	14.74	1884	9.95
1906	13.46	1883	10.93
1905	13.28	1882	12.93
1904	13.26	1881	13.10
1903	12.62	1880	13.01
1902	12.07	1879	13.26
1901	11.43	1878	10.37
1900	10.31	1877	12.01
1899	9.13	1876	10.80
1898	9.00	1875	12.20
1897	9.07	1874	13.25
1896	7.94	1873	14.19
1895	8.12	1872	14.86
1894	9.06	1871	15.74
1893	9.50	1870	15.40
1892	10.10	1869	14.67
1891	11.76	1868	14.17
1890	11.03	1867	15.09
1889	8.99	1866	14.17
1888	10.30		

trouble to produce food in 1886 as in 1871, and he produced the same amount per acre,

but in the latter year he was paid only a little more than fifty cents on the dollar for his pains. During the next ten years the nearest he came to a decent living was in 1891, when an acre of food was worth $11.78, thanks to drought. Five years later his fortunes had sagged until they touched the low water mark, with returns of only $7.94. That sum scarcely repaid the farmer for the labor of sowing and reaping; and if he considered such a thing as land being capital in those days, and the rent which capital exacts even before labor is paid, he would have had nothing for his labor.

But we began to grow hungrier again about the time of the Spanish-American War. The tariff, with its artificial stimulus to production in the arts, was beginning to work smoothly; manufactures (in which capital confiscated the subsidy that had been laid in the name of labor) began to flourish; the Jeremiahs retreated from the farms and those who stayed had to fight bugs, blight and fungus diseases, the growing pains of new land; the tide of immigration from southern Europe—people who did not know how to farm and did not want to learn—turned toward flood. Food and hunger began to run parallel again, and

in another two or three years hunger got ahead of the food supply and stayed there.

Then the farmer who had stayed on the farm, who had refused to heed the call of the cities, began to come into his own again. His acre which had paid him only $7.94 for a given amount of labor in 1896 suddenly began to pay better dividends. It touched the prosperous figure of $16.42 in 1909—higher even than inflated Civil War figures—and continued on up the scale, though a too-bountiful crop in 1910 caused it to pause for a few brief months.

What about the price of land, the value of land, during this fifty years of the ups and downs of the American farmer? Land is valuable in proportion to the demand for its products. If this is true, then the acre that paid its husbandman $15.74 in 1871 and the acre that returned $15.49 in 1910 should have possessed the same selling value.

Yet what is the fact when we come to look at the figures? The fact is that the acre which exacted a definite amount of labor and paid a definite return could be had for fifteen dollars in 1871, while it sold at $32.40 in 1910.

And, furthermore, this same acre which yielded only fifty cents on the dollar in 1896 was still considered worth about fifteen dollars by its owner in that depressing year.

These figures are not as paradoxical as they seem. The United States had, in the beginning, nearly one billion acres of fertile arable land to *give away*. Land that is to be had for the asking is not worth anything in dollars and cents for itself. The only value homestead land possessed in the early days of farming was due to the amount of labor expended on it to subdue it for the plow. The homesteaders believed that about $15 worth of labor must be expended on the average acre, and so long as there was free land to be had for the asking the owner could not exact a higher price. Land was not capital, although it frequently returned to labor over one hundred per cent. gross on its market valuation. From the Civil War on until 1900 the census returns report the value of farm land as hovering about fifteen dollars an acre. But with the beginning of the new century there comes a change. *There is no more land to give away.*

The price of food is too high. We have solved this problem more than once before in

our history—or rather we have let it solve itself. If two acres did not produce enough food it was easy to plow three acres. It was

POPULATION AND NUMBER OF FARMS AND LAND IN FARMS

Year	Population		No. of farms		All land in farms	
	Number	Per Cent. increase	Number	Per Cent. increase	Acres	Per Cent. increase
1910	91,972,266	21.0	6,361,502	10.9	878,798,325	4.8
1900	75,994,575	20.7	5,737,372	25.7	838,591,774	34.6
1890	62,947,714	25.5	4,564,641	13.9	623,218,619	16.3
1880	50,155,783	30.1	4,008,907	50.7	536,081,835	31.5
1870	38,558,371	22.6	2,659,985	30.1	407,735,041	0.1
1860	31,443,321	35.6	2,044,077	41.1	407,212,238	38.7
1850	23,191,876	.....	1,449,073	.....	293,560,614	.....

VALUE OF FARM PROPERTY

Year	Value	Per Cent. increase	Per farm	Per acre of land and buildings
1910	$40,991,449,090	100.5	$6.444	$32.40 [a]
1900	20,439,901,164	27.1	3,563	15.57 [a]
1890	16,082,267,689	32.0	3,523	21.31
1880	12,180,501,538	36.2	3,038	19.02
1870	8,944,857,749	12.1	3,363	18.26
1860	7,980,493,063	101.2	3,904	16.32
1850	3,967,343,580	.....	2,738	11.14

a. Value of land without buildings.

merely a question of inducing a homesteader to expend about $15 worth of his own time on a piece of prairie sod and plant corn. The soaring price of food in the last ten years has tempted more and more men—and women—

to embark in the business of growing food. Hordes have crowded the Land Office, men and women who would be given the opportunity to plow the third acre.

But the third acre was hard to find. In 1900 the floor space devoted to agriculture was 838,000,000 acres, an increase of 34.6 per cent. over 1890. But in the next ten years, when the greatest pressure in our history was being brought to bear on our farms to supply food, the best we could do was to add 4.8 per cent. acreage to the floor space of a manufacturing plant whose efficiency was still being measured by the sunshine-and-rain rate of production. And, at that, it was accomplished only by sorting over the remnants, from which we were able to glean only 40,000,000 acres, bringing the grand total up to 878,000,000 acres. Toward the end of the last decade land suitable for farms had become so scarce that home-seekers stood in line and drew lots. Of every hundred who filed claims one would draw a prize from the lottery, and in the majority of instances the so-called prize was of such a forbidding character that old Jeremiah of a generation ago would have passed it by in fine scorn. Right here is where intensive

farming and the reclamation of waste land enter as factors in the process of development of our national industry of agriculture. But that is another story.

* * * * *

It is interesting to trace the last step of the American farmer in his expansion over cheap land. During the last decade, the East and the South Atlantic States actually retreated, abandoned farm areas, giving up more than one million acres for one cause or another—principally because vast areas in these states, reclaimed by early settlers, were permitted to revert to forest from which they never should have been cleared.

The Middle West, the land of milk and honey, lying, roughly speaking, between the valleys of the Ohio and Missouri Rivers, and south of the forty-fifth parallel of latitude, practically stood still. In other words, the cream of the land, that yielding the largest returns with the smallest amount of labor, had disappeared entirely even before the beginning of the new century. We can except from this territory only a portion of the new State of Oklahoma, which was given over to white settlers during the closing years of the old cen-

tury after the Indians had been pushed still farther into the arid West.

Oklahoma, which crowds the dry-land belt lying between the prairies of the Middle West and the mountains, furnished six million acres for the late-comers, and with the final entry of this strip as homesteads, the last of the "inexhaustible West," the last of land susceptible to the type of agriculture that the pioneers knew, disappeared from the continent.

Those who followed found only the semi-arid Great Plains and the inter-mountain regions and the arid Southwest to be had for the asking. Twenty years ago it was the verdict of qualified students that eventually less than twenty per cent. of the bench lands lying between the ninety-ninth meridian and the mountain wall would ever be available for agriculture. It was not a question of innate fertility of the land, but lack of water. The ninety-ninth meridian marks, roughly speaking, the twenty-inch rainfall. The prosperity of the Middle West depends on an annual rainfall of not less than thirty-five inches, and once we cross the line we must change our type of agriculture. The early movement toward the taking up of these semi-arid lands

was to the southwest. The hardship and disaster that have followed in the wake of this movement have since served to develop one simple truth, i. e., that, if these lands are to be made available for farming at all, the farmer must take into account the ratio between rainfall and evaporation. Toward the south, twenty inches of rain means less than toward the north. Arid bench lands in the intermountain valleys of the State of Washington, for instance, can produce wheat with ten inches of rain because the task of retaining the scant moisture in the soil to feed the crops is more easily accomplished than in the South. Texas fails to grow wheat with twenty inches of rain because of the greedy sun. During the last decade in western Texas—a state larger and more fertile than the German Empire—settlers abandoned thirteen million acres of range, upon whose waterless plains their folorn hopes had led them a decade before. Consider what this means. An area equal to New England, excepting Maine and New Hampshire, reverted to the range.

Yet, in the fact of the cruel experiences of these "nesters" in the Southwest, the last legion of the army started in motion by the

Homestead Act dared the new problems of the Great Plains further north. Western Kansas, Nebraska and the Dakotas enrolled forty-five million acres that seemed to promise a livelihood in the business of manufacturing food for a hungry people, either through dry-farming or irrigation. The Pacific States added another four million. The line is still alternately advancing and retreating out over the inhospitable plains, the region which Washington Irving, in 1835, whimsically pictured as the habitat, the last refuge of a horde of mongrels and scamps driven from fertile prairies by advancing settlements.

Thus the last of the free land available for farming is gone. The great area of cut-over forests in northern Michigan, Wisconsin and Minnesota north of the forty-fifth parallel added another four million acres for those hardy souls not to be daunted by the task of grubbing a soil to render it fit for the plow. The South—Mississippi, Alabama, Georgia and Florida—added another two millions in cut-over lands and drained swamps.

The money value of the products of an acre of land in 1896 was only one-half what it was

in 1871. The value of the same acre product to-day is more than twice what it was in 1896. We have seen that the price of land, cultivable land, remained practically unchanged for half a century. Men figured land as worth only the value of time necessary to fit it for the plow, so long as there were other virgin acres to be had for the asking.

But what happens when there is no more land to be had for the asking? The answer is told in the census figures for 1910.

The tax value of the average acre of farm land in 1900 was $15.57.

The tax value of the average acre of farm land in 1910 was $32.40.

The increase in land values in those ten years was 118.1 per cent. Land has suddenly become capital, means something beyond merely a means of labor. For every $100 that land possessed in value in 1900, it increased $11.81 annually during the next ten years.

Stop a moment and consider what this means, particularly in relation to the so-called "back-to-the-land movement." These figures apply to the average acre nominally in farms — 878,000,000 acres in 1910. It weighs in the same scale the unproductive

acre—and nearly two thirds of the land in the possession of the American farmer to-day is unproductive — and the acre under the highest form of cultivation. In the vicinity of New York there are truck farms paying, besides wages to labor and profits, interest on a capitalization up to $2,000 an acre. The same is true of large tracts of land in the Far West—highly cultivated orchards under expensive systems of irrigation. They all go in the scale, together with the swamp and scrub land. In the Middle West, where a large proportion of the farm land is actually producing food (Iowa plows ninety-seven per cent. of her dominions), the price of an acre varies from $75 to $250 and touches $400 near large cities. These figures have nothing to do with the present stage of the discussion, but are cited merely to give emphasis to the term "average acre."

The fortunes of the Jeremiahs who stayed on the farm when there was no one so poor as the farmer form a strange contrast indeed with those of his brothers who flocked to the cities when hogs touched two cents on the hoof and corn was fed to the stove.

Hetty Green, the woman financier, speaks

of the savings bank as the best form of investment of funds. Yet the American farmer who hung on has seen his dollars, invested in land, return him an increment—unearned and apart from the wages of labor—*three times as large* annually as savings bank interest. Hardhack goat pastures and mellow prairie loam fertile with the decaying vegetation of thousands of years have doubled in value in less than nine years. The "unearned increment" with which the American farmer has been buying automobiles and gasoline tractors in these ten years put more money in his pocket annually than the utmost labor which he and his sons were able to expend on an acre of productive land—not scrub land—in any single year between 1883 and 1902.

The mere possession of an acre of improved land has become more valuable to the landlord—throwing out the item of "rent" entirely—than the sweat of the brow expended by his tenant farming at the sunshine-and-rain rate which has guided our husbandman since his fathers went "west."

Land has suddenly assumed value as an investment, not alone for what it can produce in food, but, in addition, because it is a magic

purse which has doubled its contents in less than ten years.

The reason begins and ends with the hunger of the world and the supply of the land—the limited floor space available for producing food. William H. Taft, in a recent address before a Conservation Congress, predicted that the United States will have attained a population of 200,000,000 in another fifty years at the present rate of increase. The industry of farming represents a capital of nearly fifty billion dollars. The single item of land, without buildings, accounts for twenty-eight billions of this stupendous sum. To what total in dollars and cents will the item of land attain when each acre of to-day is called on to feed two mouths for every one it feeds now? We are already ceasing to export wheat.

Is it not a remarkable fact that an industry which still depended on a subsidy at the beginning of the present century, for further expansion, should have attained a capitalization nearly fifty times that of the world's greatest business combination in one decade? Land, water, timber and minerals, in the beginnings of a nation, are valuable only in proportion

to the labor they consume—until there is no more to give away. Canada, Brazil and the Argentine are to-day in the midst of the same process as regards land from which we have only now emerged. The mediæval way was for the sovereign to take what he desired, providing only his spears numbered more than his neighbor's. Then the conqueror would parcel out the land among his nobles, who, in turn, impressed their serfs as labor. The history of England is that of one distribution of land following close on the heels of another until the Conqueror set up a permanent order in the eleventh century. Yet, even with the task of the distribution of land simplified by the system of royal warrants among favorites, agriculture did not become established as an industry in England until three centuries later. In 1350 England saw the last of the crown lands pass into private hands, and at that time she was plowing as great an area as she is to-day.

This republic found a different task confronting it. To establish its agriculture on a permanent basis, it must parcel out a domain aggregating nearly one billion acres to individuals in small holdings, a quarter-section, of

one hundred and sixty acres, being adopted in the beginning as a standard.

In 1800 the area of the United States was 892,135 square miles, and the acquisition of Louisiana and Florida increased the area to 1,792,223 square miles in 1820. Then came Texas, the Spanish Settlements in the southwest, the Gadsden Purchase, and the readjustment of boundary lines, until, in 1853, we possessed 3,026,789 square miles, comprising continental United States, excluding Alaska. In 1800 there was a population of five million. In 1853, when the nation had expanded to its ultimate limit, it numbered nearly twenty-five million souls, about eight to the square mile—eighty acres to every man, woman and child.

The first concern of the established government was to foster agriculture—to provide food for its people. In fact, as early as 1743 the British Government appropriated $600,000 to encourage the cultivation of indigo and other crops in the colonies. The colonies themselves set aside small sums to encourage new lines of agriculture—hops in Virginia, mulberry trees for silk culture in Georgia, and grapes for wine growing. Franklin, as the agent of Pennsylvania in England, sent home

silk worms and eggs and mulberry cuttings, and Jefferson, as minister to France in 1785, sent seeds of various grasses and olives and peppers. It was he who started experiments in rice culture in the Carolinas, an industry which was later destined to produce the finest rice in the world, from a fine strain of old-world plants of which he dispatched a handful of seed.

Under John Quincy Adams instructions were sent to all consuls at foreign ports to gather rare seeds and plants, to be distributed through the office of the Commissioner of Patents among agricultural societies, and a horticultural park was established in Washington—our first experiment station. So even at that remote period, when the loom, the spinning wheel and the soap kettle seemed forever established as domestic necessities—when land and the products of land were so bounteous that the people had no conception of their ultimate extent—even in those days the founders were already looking forward and preparing for the economic problems that would confront their descendants. How remote the time would be when their people would be in want for lack of land and the

fruits of land is reflected in the prophecy of the novelist Cooper, when he said that the resources of the single State of New York were sufficient to feed its people for ages to come.

In those days the main question was what to plant, not where to plant it. From the Indians they had corn and tobacco, and the same corn was destined in another hundred years to produce for the nation one million dollars an hour for every daylight hour of its four months' growing season.

It has taken over a century to find out how far the land would go—to ascertain how much of the grand total of 1,937,145,000 acres (exclusive of lakes and rivers) would eventually prove arable, would offer sufficient inducements to the pioneers of the industry of farming to expend their labor thereon.

Eleven decades of growth, during which the population increased to nearly one hundred millions, finally answered the question, finally brought the basic industry of the nation to the end of its initial stage of development—where land becomes capital and exacts its tithes no less than labor. These facts mean nothing if they do not impress the reader that he who goes back to the land to-day is the

pioneer of a new industry, an industry which is just beginning to find its feet after a hundred years of subsidy.

* * * * *

There is no subsidy awaiting the Farmer of To-morrow. And, what is more, he must to-day compete with the Farmer of Yesterday, the pioneers and the sons of pioneers and the late-coming hordes who bought land on the basis of the amount of labor required to subdue it—not on the ultimate basis of the producing power of the land itself. It would be idle to attempt to arrive at a definite percentage of the Farmers of Yesterday who are surviving to see the old order changing. It is suggested that with the beginning of the second decade of the present century upward of seventy per cent. of the competitors our modern Jeremiahs must face in the business of producing food have not yet come to the realization of what is meant by the term "rent." Even the item of "tenants" enumerated in the 1910 census returns as comprising thirty-seven per cent. of our 6,340,000 farmers, means little or nothing in this connection, because the old system of farming on "shares" is still the rule between landlord and tenant.

The situation existing between the Farmer of Yesterday and our Jeremiah who goes back to the land to-day is that of two brothers engaged in the same business as competitors, one outfitted by his parent with the tools of production and the other forced to expend interest-producing capital for the same plant. The only way in which our Jeremiah can compete with his subsidized brother with the same tools—and there are none better to be had—is by increasing the efficiency of his plant—by speeding up and producing beyond the sunshine-and-rain rate of production that contents the Farmer of Yesterday.

The subsidized farmer of to-day is a prosperous individual for this one reason: the $16 or $17 he is now receiving for the product of his average acre is still wages to him, nothing more. His land cost him nothing; then why should he keep books and pay tribute to Capital when his land, so far as he is concerned, is still only a means of labor? Yet that is the very first account to eat in on the returns of the man who goes back to the land to-day, and when he scans the result he finds that his antiquated methods leave him bankrupt. With him it is not the simple act of

taking money out of one pocket and putting it in another. He has come to know what capital means, what it exacts, because he must buy his plant before he can begin to expend his labor on it. Yet his brother, still vastly in the majority, rolls his receipts into one and calls them wages—and very good wages they are indeed, when labor is so favorably situated that it can usurp the tithe of rent.

And, in addition to pocketing as wages that portion which we late-comers must pay as interest on capital, he has lived to see a sensational rise in the value of his land itself, through no effort on his part—a bonus to the individual from a source which Mr. Albert Jay Nock (American Magazine, November, 1912) calls "the social value of land." He calls attention to the fact that every increase in population of the City of New York reacts upon real estate values as definitely as does the increase in steam pressure react upon a steam gage. He cites the fact that the birth of a child, a pauper, weak and rachitic though it may be, adds $849 to the aggregate value of New York real estate. A hundred men out of employment, sleeping on park benches, producing nothing, consuming charity, add, by

their presence alone, $84,900 to the city's realty values.

Now apply this same idea to the 878,000,000 acres of farm land with which the American farmer has been subsidized by his government. The same idea applies here, though in another phase. Land in cities depends for its value on the desire of a mass of people to get together in the most favorable place to carry on the process of manufacture and distribution. Farm land, the limited floor space of the food plant, depends for its value on *the number of mouths to be fed* by its products.

We have seen that the birth of a child adds $839 to the value of the city's real estate. What does the birth of a child, the addition of one to the population of the United States, mean to the pockets of the Farmer of Yesterday, who "hung on"? What does the admission of every single soul of the ten million aliens who flocked to our shores during the decade ending in 1910 add to the value of land—farm land?

The answer is a simple problem in arithmetic. The increase in population in ten years was sixteen millions. The increase in the dollar value of the farm land in the same period

was *fifteen billions.* Every new-born child, every "undesirable alien" enumerated among that sixteen million, added *nine hundred and thirty-six dollars and eighty-six cents* to the value of our farms. Even New York, with its five million souls and its Stock Exchange land assessed at thirty thousand dollars a front foot, does not compare with the domain of the American farmer who has "hung on."

Some may object that the comparison is inept. They will say that it would hold good if the population of the United States consumed all its land produced. But it does. That is the point. And more. Exports of food-stuffs fell from over twenty-five per cent. of the total produced in 1898 to less than five per cent. in 1912. And imports of the same commodities had the better of it by a ratio of 230 to 99 (in millions of dollars value) in the latter year. We consume even more raw food-stuffs than we produce.

Every Jeremiah who goes back to the land adds to the value of that land by his mere presence. To quote again from Mr. Nock's article, he is in the position of a lecturer, who, arriving late at a small town, found no one to meet him. He was unknown to the door-

keeper and had to buy a ticket to hear himself lecture.

Farmers' Bulletin No. 511, on farm bookkeeping, recently issued, ventures the assertion:

"There is reason to believe that the majority of farmers are really living on the interest of their investment rather than on the profits of their farms."

And again:

"Many farmers would be better off financially if they sold their farms, loaned the money at five per cent, and hired themselves out at current wages."

These statements may be true, except for one factor the writer overlooks—*the social value of land.* If he had said that the farmer would be better off if he rented his land, even on the usual unbusinesslike basis of "shares," and hired himself out at current wages, then he would have broached a glittering possibility. No matter what the Farmer of Yesterday does, he must "hang on"—no matter whether he works his acres at the antiquated sunshine-and-rain rate or lets some one else do it for him. The American farmer has doubled his

capital in less than nine years by doing nothing but "hang on" and counting the increasing number of mouths to be fed from his limited floor space. That, after all, is the source of the greatest profit in farms in the last ten years, and must continue to be so, in increasing ratio. It is better business even than the sleight-of-hand performance of pocketing rent in the name of wages as he did twenty years ago—and as the old-line farmer is still doing to-day.

All of which brings us back to the editor and his advice to the back-to-the-lander with the paltry five thousand dollars.

CHAPTER III

THE GLEANERS

However, there is another side to the question—happily for Jeremiah who wants to go back to the land. When the statement is made that all our public lands have at length passed into private hands, it may mean everything or nothing, according to one's viewpoint. It does mean, for instance, that there is no more free arable land to be had for the asking. It does not mean, however, that all of the land nominally in farms is actually under cultivation, is actually producing food.

The Bureau of Soils, of the Federal Department of Agriculture, made this statement in 1898, in reviewing the soil resources of the United States:

"Although practically all of the arable land has now passed into private hands, less than one-fourth of the land nominally in farms is actually under cultivation."

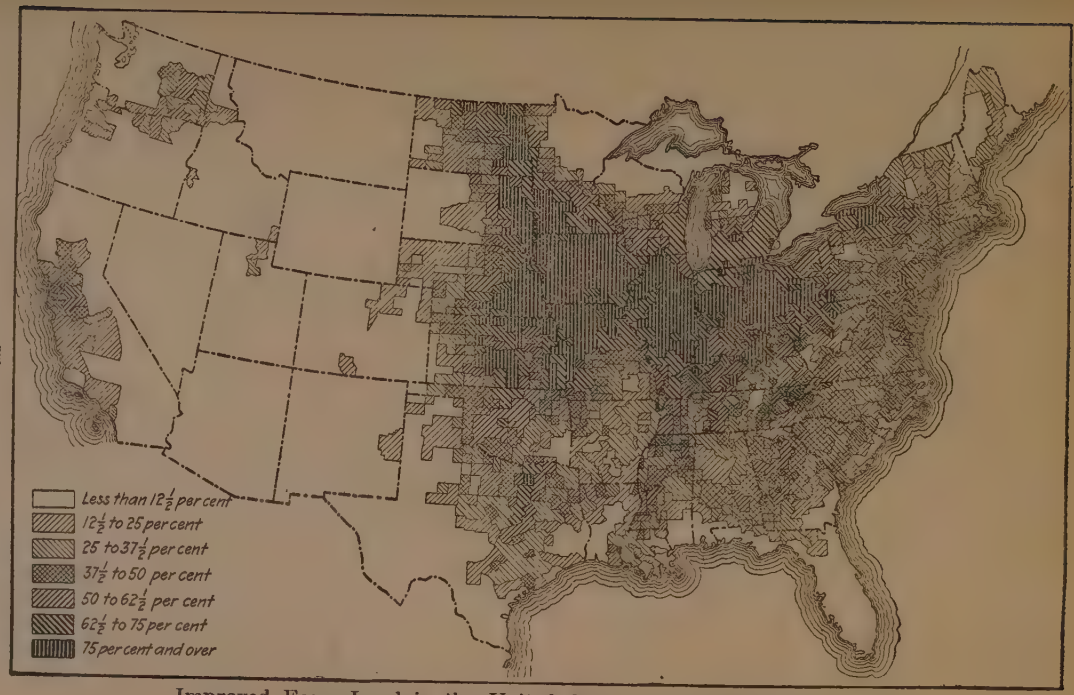
This statement does not assume to be specific. The Bureau of Statistics of the Department of Agriculture has since narrowed the measure of cultivated land down to actual acres and percentage of the whole. In determining the value of the product of an acre, these statisticians chose wheat, corn, oats, barley, rye, buckwheat, potatoes, tobacco, hay and cotton as constituting ninety-five per cent. of the cultivated area of the United States. During the closing years of the first decade of the present century the acres devoted to these crops had begun to mark time after nearly a century of uninterrupted advance. The figures for 1910 are representative and are given herewith:

Corn	114,002,000	Potatoes	3,591,000
Wheat	49,205,000	Rye	2,028,000
Hay	45,691,000	Tobacco	1,234,000
Oats	35,288,000	Buckwheat	826,000
Cotton	32,403,000		
Barley	7,257,000	Total	291,523,000

Adding the remaining five per cent., we have roughly 307 million acres actually under cultivation. It is this three hundred and seven million acres, together with its buildings, machinery and live stock that constitutes the bulk of the fifty billion dollars of capital invested in farming.

We have already seen that 878,000,000 acres are nominally in farms. What has become of the remaining 570,000,000 acres—an area twice the size of the German Empire and France combined—which the homesteader has proved as farm land and upon which he is willing to pay taxes on an average acre valuation of over thirty-two dollars. The answer is vital to the Gleaner.

The census enumerators adopt a system in accounting for the arable area that is a little more flexible than that of the statisticians who count crops. The census enumerators rank 477,000,000 acres of the total of 878,000,000, as being "improved"—that is, in addition to being cultivated, a large area of it is devoted to pastures and wood lots. This figure still leaves over 400,000,000 acres nominally in farms, as standing idle in the face of the soaring prices of food. Is it not a striking fact in relation to an industry which counted its plant—its land—as worth $28,000,000,000 in 1910, that nearly one-half of that land was idle and non-producing at that time? Over 400,000,000 acres has been accepted as a gift, and, found to be too stubborn for cultivation so long as there is mellow land in


Less than 12½ per cent
12½ to 25 per cent
25 to 37½ per cent
37½ to 50 per cent
50 to 62½ per cent
62½ to 75 per cent
75 per cent and over

Improved Farm Land in the United States Thirteenth Census, 1910.

sight, is filed away on the back shelf for future reference.

Let us call the original pioneers the "Reapers." They picked and chose with discriminating taste. When we read the early history of the expansion of the American farmer over the rich prairies, we find the same picture of waste that we find in the early romances of the plains, where it was usual for a huntsman to slaughter a giant buffalo for its succulent tongue alone, abandoning the huge carcass to carrion. The early settlers cast aside millions of acres that were not prime and ripe for skinning in their rush to find the fat river-bottoms, where the least amount of labor would furnish the maximum returns. Man is innately a conserver of his own labor, with no urging. The same spirit is evidenced to-day in the high capitalization of these identical river-bottoms of the western prairies. The land which will yield most bountifully for the least amount of labor must always be the most valuable in the eyes of a race that is a conserver of its own labor first and foremost. With the exception of the earliest pioneers in New England (who built uncounted miles of stone walls and grubbed stumps in

reclaiming land that never should have been put under the plow) the early Reapers tested and rejected as they advanced, seeking forever the fattest acres. If one could construct a map showing the area actually under cultivation for each of the several decades the result would show grotesque empires indeed. Note the Kentucky woodsmen in 1804, when the population east of the Mississippi was very tenuous indeed, starting forth into unknown regions with their long trains of wagons, with their women and children and their cattle. Iowa and Illinois offered no inducements to them near at home. The land was so bounteous all about them that surely somewhere in the region between the great river and the mountains there must be other empires of still greater riches. The Oregon Trail in the late 'forties was a sympton of the same unrest—greediness, conservation of labor run riot. They traveled three thousand miles with ox teams, seeking not Ultima Thule, but Elysium. It was not until after the Civil War that the homesteaders arrived in sufficient number to begin blocking off the Corn Belt systematically. The map on page 71, taken from the 1910 Census Reports on Agriculture, illus-

trates the domain of the American farmer acquired by the process of homesteading. It is especially striking in view of the oft-repeated statement that "free land is a thing of the past." It illustrates how an inexorable Nature has interposed an impregnable obstacle against the further advance of the plow on the rainless bench lands of the western plains.

Right here is the turning point between the old system of subsidized farming and the permanent order of agriculture as an industry that must stand on its own feet. Here the Farmer of Yesterday becomes an anomaly and the Farmer of To-morrow enters to take up the task of producing food. Here is where our Jeremiahs enter, go back to the land, facing new problems, new conditions. And when we have examined the field that lies before the pioneers of the new industry of farming who will say that their opportunities are not immeasurably brighter than those of the Farmers of Yesterday who went west with their yokes of oxen and their iron kettles?

The industry develops from this point along

two distinct lines, distinct as to method, yet marching toward the same goal:

First, comes the reclamation of waste land.

Second, comes the intensifying of cultural methods—forcing each single arable acre to produce two or three times as much food as it produced under the elemental system guided by the sunshine-and-rain gage of production.

The Farmer of To-morrow must either speed up the rate of production on fat, highly capitalized corn-belt acres, by means of an additional expenditure of capital or else look about him for raw, non-producing land, upon which to expend his labor to fit it as a competitor of the fat acres which are beyond his means.

When a horse begins to eat its head off there are two ways out of the difficulty: Either work the beast hard enough to earn its keep or look about for a means of transportation with a more reasonable appetite.

Land has the habit of "eating its head off" too. It becomes greedy when it becomes scarce, when it assumes value. It exacts interest—rent, and finally rent grows so greedy that there is nothing left for wages. Then

is the time to apply the horse medicine. Either work it hard enough to pay its keep (this costs time and money just as full steam consumes more coal than half steam) or look around for land that exacts less.

Take a concrete example. It requires a two-million-dollar plant—a twenty-story sky-scraper—to show a profit on a building site at Broad and Wall streets, New York City, where land is assessed at $30,000 a front foot. Not so very long ago a site at this corner was occupied by a two-story building. The owner sold out when the cost of keeping the property began to eat up his profits. Then a syndicate with time and money erected a two-million-dollar sky-scraper on the site, thus working the plot of land hard enough to pay its keep. The original owner moved further up town, where a cheaper lot answered his modest needs.

Farmers adopt the same plan. Seven hundred thousand farmers have crossed the line into Canada in ten years—moving "farther up town." Many of them, of course, possessed only a railroad ticket, having come too late to find a homestead under the Stars and Stripes. But a goodly number were farmers from Illinois and Iowa, carrying satchels full

of "unearned increment." Corn belt acres had begun to demand too much coal to start the boilers according to their way of farming.

These two types of farmers are growing to be clearly defined now that the last of our public land has passed into private hands. One is like the owner of the two-story building on the sky-scraper plot. When land values get beyond his methods he either improves his plant or sells out to some one who can, and migrates to cheaper land. The best is too good for him. He will take second best if he can find it.

The other type—and it still numbers nearly seventy per cent. of the farmers of to-day—is like an old druggist in lower Broadway, New York City, who won local fame by refusing an offer of enough five-dollar gold pieces to cover his plot. He refused to sell. Why should he sell, he argued? He got his plant for nothing—inherited it from his father when Canal street was a cow path. His pills still pay his taxes and keep his roof whole. That is all he wants.

Of the latter class are the competitors, our hypothetical friend, Jeremiah (whom we met in the first chapter), encountered when he bor-

rowed money to buy an Iowa farm on his back-to-the-land venture. He found he could not compete with the man who looked upon his land merely as a means of labor because he got it for nothing or inherited it from his father, like the old druggist. Nor could he compete with the new type of farmer who improved his plant. Jeremiah did not have the time and money.

Then he must become a Gleaner. If he will consult the figures a few pages back he will find that, in spite of the fact that we still call ourselves an agricultural nation, less than twenty-five per cent. of the land area of the United States is actually producing food. Throw out a solid billion acres of mountain scenery, sand and arid plateaus and we still have the 878,000,000 acres nominally in farms. Cut this last figure in two and we find 400,000,000 acres of farm land standing idle.

Germany, a nation which makes no pretensions as an agricultural state, has subdued forty-five per cent. of her total land area. The Kaiser sent a commission to study us and our industries, and the learned gentlemen went back home and reported that the Fatherland need not fear competition from the United

States until the end of our raw land was in sight—a far cry. The German, who has reduced the science of gleaning to its ultimate atom, cannot understand why the cost of living should be a problem among us when we ignore three out of every four acres, good and bad. And the Hollander, entering or leaving New York City (with its market made up of the hunger of five million people), cannot understand why the Newark Meadows—almost as big as their Harlem See—is not reclaimed from the tides and set to growing vegetables. Germany supports sixty million people on an area smaller in size and less fertile than our single State of Texas—and Texas is one-third arid.

It is these three out of every four acres that we do not farm that are of supreme interest and importance to the Farmer of To-morrow. In these three out of every four acres there is land to be drained, land to be irrigated, land to be cleared of tree stumps left in the wakes of a lumbering industry that had ruthlessly slashed and burned with no thought of the morrow. And there is land to be humored with specialized crops. Let us follow out the process of gleaning that is already under way,

and, while we are tracing the opportunities and problems of the late-comers, the Farmers of To-morrow, we will arrive at an estimate of what the cultivated farm area of the nation must eventually number in acres to feed the hordes of another hundred or another five hundred years.

Let us take a specific instance of how the problem of cheap land was actually worked out by one division of the army of Gleaners.

Several years ago some Illinois farmers (homesteaders or fire-sale investors of a generation ago) found that the pace of their fat prime acres was growing too hot for them; so they sold out and pocketed their unearned increment—which had increased 118 per cent. in ten years without any effort on their part. They might have gone to Canada and got a quarter-section at $1.25 per acre and another thrown in for good measure. But they didn't go to Canada. They had an idea that opportunity lay just outside their door. And they found it in an embryonic stage.

It was just across the river from them, on the west bank of the Mississippi. It was the far-famed Iowa Slough.

The slough was a great place for ducks—that was all they knew of it at first—and if there is any land in the world more downright good-for-nothing as farm land than a duck slough they would like to see it. This patch was a strip of swamp forty-one miles long, containing forty-five thousand acres, just north of the town of Burlington—a bottomless pit of muck to catch the wash from the prairies. So far it had failed to attract any attention outside of sporting circles, except for a line in the mortality statistics every ten years —a line running something like this:

"Deaths from malaria, per thousand total, 52.5 in 1870."

The State of Iowa had accepted it with the scorn of a well-fed tramp back in 1850, when the lawmakers at Washington, finding that land was not being given away fast enough by any of the methods then known, devised a statute transferring all the swamp and overflow land to the various states.

A suspicion that they might be giving away more than they knew caused them to limit the gift eight years later to the states actually

enrolled in the Union in 1850, and two years later to include Oregon and Minnesota.

This particular swamp, like all others, produced nothing but chills and fever for another generation. Along toward the 'eighties it began to be a positive nuisance, because at high water steamboats plying the river got into the habit of getting lost among its bogs and bayous. The government thereupon walled in this slough with a good, strong levee—not to encourage agriculture, but to keep the river in its proper place.

A few adventurous settlers, returning from western Kansas with the tale of its having forgotten to rain out there for five years, squatted back of the river wall. A village sprang up on a bump of muck. It was called Oakville; later, Oakville Prairie—by courtesy—there being no prairie in sight except on top of the bluff. Oakville didn't thrive. It wasn't a boom town. The wash from the hills, the seepage from the river, and the spring rains kept it pretty well submerged. And the cost of quinine outran tax bills.

Then an imaginative seer, whose name has been lost in the whirl of subsequent events, propounded this query:

"If it pays to pump water *into* an arid township west of the rain belt, why wouldn't it pay us to pump water *out?* Water—too much of it—is all that stands between us and prosperity."

The suggestion to undertake the task of pumping the water out of a forty-five-thousand acre catch-basin as full of holes as a sieve did not catch on very fast in Oakville. But the State of Iowa officially inclined an ear.

Iowa plows ninety-seven out of every one hundred acres in her dominion, and she was beginning to worry over the increasing number of her farmers who were cashing in their unearned increment and escaping with it to Saskatchewan. Her engineers went to work quietly, and shortly they had the upper seventeen thousand acres of the Iowa Slough organized as the Louisa-Des Moines Drainage District No. 4. Almost before the web-footed farmers splashing around in their corn fields back of the river wall knew what was happening, steam dredges began scooping arteries and laterals among the muck and ooze.

Now it takes a community, especially a malarious one, a long time to wake up to an idea. Oakville slumbered on for a year or two.

Then—enter the Illinois farmers who had sensed opportunity close at hand. They entered by twos and threes, so as not to arouse suspicion. They began buying land. They offered ten, fifteen, twenty-five, finally fifty dollars an acre for the duck pond. A fair proportion of the natives swallowed hook and sinker. They had got their land for a few cents or a few dollars an acre, and the current quotations seemed to discount prosperity beyond posterity.

But a good many of them held on, and—for a few years more ate quinine and watched the toothing steam dredges.

Six years passed and still there was nothing extraordinary in the appearance of the duck preserve. There was just as much water as ever. Nestling against the river wall, half way down toward Burlington, however, there was a low-lying house of cement. Duck-hunters with sufficient curiosity to peer in at the windows would have seen a lot of queer-looking machinery standing knee-deep in water. That collection of machinery consisted of two three-hundred-and-fifty-horse-power engines calculated to drive two fifty-inch pumps.

After a while the pumps began to work. Each had a capacity of one hundred and fifty thousand gallons a minute, three hundred and fifty second-feet; enough water, if driven through a Gunnison Tunnel or impounded behind a Roosevelt Dam, to capitalize sixty thousand acres of the land west at one thousand dollars each. The malarious little village of Oakville Prairie rose out of its wallow gradually and surveyed its environs. It surveyed seventeen thousand acres of corn land richer than a green house, as fertile as Egypt.

To-day, where the duck-hunter used to punt his scow, there are hard, level roads, grain elevators, fenced fields, and diversified farming of the highest type. The only lament is the lament of lost opportunity. The former amphibians who sold out at fifty dollars are the saddest of the lot. The twenty-seven thousand acres of the lower district were surveyed and contracts let, and in another few years the old Iowa Slough will have passed forever into history.

Incidentally, this and other drainage work in Iowa and Illinois has reduced the death-rate from malaria from 52.5 to 8.6 per 1000 since 1870.

And what did it cost?

It cost $9.31 an acre! Spread out thin in ten annual instalments. The pumping plant is maintained at a small cost pro rata, like a coöperative irrigation system. One pump handles the spring floods very easily. Gravity takes care of the drainage during the normal stages of the river.

The former amphibians no longer dread the spring rains. Every shower washes down the fertile silt of the highly capitalized Iowa prairie up on the bluff, to add to the bank account of Oakville. Therefore Oakville, dry-shod, has become capitalized itself and has built a railroad to tap this miniature Holland in America north and south.

This and hundreds of other similar communities that have been reclaimed from muck beds since the beginning of the end of free land came in sight are the anomalies of a rapidly expanding industry. In dollars and cents returns, these reclaimed areas present sensational results. Their owners find railroads, markets, all the advantages that have served to capitalize prairie acres at figures ranging to and beyond $150, and the deep beds

of silt deposited by centuries of erosion provide, once drained, a bank account of fertility even beyond the greedy dreams of the early Reapers. There are undrained swamps in Louisiana where soundings two, or even three, thousand feet in depth have failed to find bottom in the alluvium.

Naturally, reclamation and expansion over prime free land overlap. And when we seek to ascertain in what localities reclamation projects first appear, we look to the districts where the surrounding acres are producing most bountifully and, therefore, are highest in price. The first great projects were among the rich plantations in the lowlands fringing the Gulf of Mexico, lands devoted to sugar cane and cotton. But the projects were isolated, little heard of, until wise farmers in the Mississippi River Valley began to look ahead, about the beginning of the last decade of the last century. The prairie farms about the Illinois River, in the State of Illinois, and adjacent portions of the Mississippi River have for fifty years held the blue ribbon among our acres, and early became so highly capitalized that the late comer who would conserve labor as the worker of these fat acres was

forced to pay the price. It became simply a question of dollars and cents with the owners of these swamp lands, and when the States themselves stepped forward and offered to undertake the task, providing coöperation could be secured among the owners, the movement was under way. Nevertheless, though pumping was attempted as early as 1890 along the Illinois River, it was not until five years later that any considerable areas were mapped as "projects." By that time the engineers, Federal and State, had arrived at satisfactory solutions of the difficult problems that presented themselves. By 1910 ten separate plants were in operation, aggregating 85,000 acres and utilizing 2,000 horse-power. The census showed three other projects nearing completion, adding 33,000 acres to the reclaimed tracts. Along the Mississippi, between Muscatine, Iowa, and Hannibal, Mo., over 150,000 acres of rich corn-belt land has been reclaimed by pumps and the work is still in its infancy. Coöperation has been the means of accomplishing the addition of this magnificent empire to the States of Illinois, Iowa and Missouri—coöperation and the conviction on the part of the law makers that

such work is a public function and deserves the aid of the States. Tracts as small as 3,000 acres have been drained profitably, but, in general, it has been found that the cost per acre is lower in proportion to the size of the tract, and 10,000 acres has been adopted as the most economical unit. As to the cost of reclamation, the following paragraph from Bulletin 243, Office of Experiment Stations, "Land Drainage by Means of Pumps," gives a definite statement of the experience of these Middle West farmers who were the pioneers of the reclamation movement:

"Experience along the Illinois River shows that the first cost of the general district drainage improvements, including ditches, levees, and pumping plants, has varied between $15 and $30 an acre. All of the cheapest projects have now (1911) been developed; however, there is a growing tendency to undertake the reclamation of more expensive districts in which the cost may exceed by $10 or $20 per acre the amount just stated. The cost of clearing the land and field drainage may be between $5 and $20 an acre. Hence, in places, the total cost for putting the land into profitable productive condition may be as high as $50 an acre. Such land is then worth

from $100 to $125 per acre, according to the present value of the contiguous uplands."

In the same survey, the cost of maintaining the plant, after it is once in operation, is approximated as between 30 and 60 cents per acre per year, and, of course, considerably lower in dry years. The reference to "dry years" suggests the wonderful possibilities that are following in the wake of this system. As these lands receive their water not only from the skies, but also from seepage, it is possible to maintain the optimum moisture content in the soil during the entire growing season, because even in dry years these favorably situated lands, once scorned, have a superabundance of ground water to be reduced by pumping.

When we hear the word "reclamation" mentioned we are accustomed to consider only irrigation, yet, in a survey of the possibilities of the empire to be added eventually to our farms by drainage—removing surplus water—we see that irrigation, sensational though it may be, is very small indeed in comparison.

As long ago as 1850 the nation began deeding its swamp and overflow lands to the various

states, as we have already seen. The thirteen original states did not profit under this grant, because at the formation of the Union they took possession of all public lands excepting only Indian reservations within their boundaries. The states that came within the meaning of the act of 1850 were permitted either to abide by the surveys of government engineers or to make their own survey and file claims with proof. Up to June 30, 1906, the swamp lands had been distributed as follows:

SWAMP LANDS CLAIMED BY THE STATES UP TO JUNE 30, 1906

State	*Acres*	*State*	*Acres*
Alabama	534,190.04	Michigan	7,293,278.93
Arkansas	8,656,372.39	Minnesota	5,472,375.86
California	2,066,253.22	Mississippi	3,604,795.93
Florida	22,273,207.98	Missouri	4,843,676.09
Illinois	3,981,784.10	Ohio	117,992.00
Indiana	1,377,727.70	Oregon	526,903.63
Iowa	4,572,816.27	Wisconsin	4,802,872.12
Louisiana	*a*11,216,831.33		
Louisiana	*b*785,270.00	Total	82,126,347.59

a Act of 1849. *b* Act of 1850.

Thus the three States of Florida, Arkansas and Louisiana have patented one-half of the total area, while the remaining area has been distributed among twelve states, although Illinois, Iowa, Indiana, Michigan, Minnesota, Wisconsin and Missouri received the bulk. The amount of swamp land still held by the Federal Government is small.

Because these tracts are scattered and isolated, it is rather difficult to obtain a clear idea of their extent; yet the area is larger than that of the British Isles. Government engineers were assigned to survey and report on the swamp and overflow lands with the idea of determining how much of the area would be susceptible to drainage. In their opinion there exists to-day an empire of 77,000,000 acres east of the ninety-ninth meridian which can be reclaimed and fitted for cultivation. Make a block of this area and spread it across the map. You will discover that it is equal to the area of the three States of Illinois, Indiana and Ohio. In the bulletin "Swamp and Overflow Lands of the United States," J. O. Wright, supervising engineer of the drainage and irrigation investigations in 1907, summarized the economic significance of this vast empire thus:

"As to the cost of draining these lands, and whether or not it will pay, we have but to refer to the numerous works of this kind that have been completed. In those States where large areas of swamp land have been thoroughly drained by open ditches and tile drains the cost ranges from $6 to $20 per acre, while

in places where tile drainage was not required the average cost has not exceeded $4 per acre. Judging from the prices which prevail in a large number of these districts where work of this kind is being carried on, it is safe to estimate that the 77,000,000 acres of swamp can be thoroughly drained and made fit for cultivation at an average cost of $15 per acre. The market value of these lands in their present shape ranges from $2 to $20 per acre, depending upon the location and prospect of immediate drainage, with an average of probably $8 per acre. Similar lands in different sections of the country that have been drained sell readily at $60 to $100 per acre at the completion of the work, and in many instances, when situated near large cities, they have sold as high as $400 per acre. To determine whether or not it will pay to drain these lands we have but to consider the following figures:

Cash value of 77,000,000 acres after thorough drainage, at $60 per acre		$4,620,000,000
Present value of this land at $8 per acre	$616,000,000	
Cost of drainage at $15 per acre	1,155,000,000	
Value of land and cost of draining		1,771,000,000
Net increase in value		2,849,000,000

Ninety-five per cent. of the land ceded by the government to the various states is already in the hands of farmers. And in addi-

tion to this empire of 77,000,000 acres it is estimated that there is upward of 150,000,000 acres additional land in the hands of farmers which could be brought into profitable cultivation by the use of drains.

Too much water is as disastrous, unless remedied, as not enough. Irrigation in the humid East has been urged as an insurance against dry seasons, and already the movement is well under way. During the past few years there have been put through to completion drainage projects in New York State which aim to impound the water which exists in superabundance in the spring for use as irrigation in the dry summer months. It is a fact worthy of notice that drainage has become a necessity even in the arid regions of the Far West, regions where farming cannot be practiced at all without expensive irrigation systems. In the single State of Colorado upward of ten per cent. of the irrigated area has been abandoned because of swamps formed by the seepage of water to the lowlands. In the past it has been found more expensive to drain these districts than to convey water to new ground for irrigation; but with the advancing price of land and especially

the high capitalization that follows irrigation, it is becoming more and more profitable to add drainage as a necessary adjunct to all irrigation systems. The results are two-fold. In the first place the surplus water can be carried off and used to irrigate lands lying at a lower level, and, in addition, it has been found that drainage prevents the accumulation of alkali at the surface of the ground. This latter discovery is of immense economic importance because whole countries have been rendered sterile by the accumulation of alkali due to the circulation of the water of irrigation.

These facts regarding drainage, its scope and economic importance, are specially interesting because we are still in the infancy of the movement.

Yet, remember that the little nation of Holland, whose acres support 450 souls to the square mile, began diking and draining its empire nearly 400 years ago, and that to-day nearly two-thirds of Holland lies below the sea level. When we think of Holland there comes before us a picture of windmills. Windmills were pumping water in Holland before Christopher Columbus sailed out on his voyage of discovery. The development of

mechanical means of lifting water out of submerged lands came when the native farmers were forced beyond the areas where gravity could be utilized to take care of the excess. The means first in use were the old-fashioned scoop-wheels and the crude Archimedean screws. In 1825 Holland undertook the stupendous engineering task of draining a district—the Zuidplas Polder—containing over 10,000 acres, and lying twenty-two feet below the level of the River Yssel. It was indeed a task for the engineers of those days, but they accomplished it by establishing two batteries of windmills, driving scoop wheels and Archimedean screws, the first battery of fifteen windmills lifting the water half way to a settling basin, and the second taking it up and over the river dike. The greatest single drainage project in history is that of the Haarlem Lake in Holland, comprising 41,650 acres. The lake was fifteen feet deep. A phalanx of windmills, their long arms beating the air in unison, were set in motion in 1852, but it was not until thirty-nine months later that they had accomplished their task of scooping out the water. On several occasions later the water got ahead of the crude motive power

and flooded the district, causing immense loss to the farmers who had crowded the flat floor of the drained area to plant and till crops. It was finally found necessary to do away with the picturesque wind mills and substitute steam power. To-day the district once occupied by the great lake is a plain traversed by a network of roads, furnishing homes for upward for 20,000 people. Three immense pumping plants of 350 horse-power each, with a capacity of 2,000 feet of water a minute, hold back the tide from the door-steps of the thrifty Dutch. England, France, Germany and Italy have followed in the footsteps of the hard-pressed Dutch, and, with the perfection of mechanical contrivances of the last hundred years, they have solved the problems of draining fens and marshes, and provided voluminous literature from which we can glean to advantage. Remember, in this connection, that the ultimate area we will have drained will add a territory as large as all France to the Stars and Stripes. In the work of reclamation there are opportunities for our new pioneers such as their forefathers never dreamed of.

CHAPTER IV

THE DRY LANDS AND THE FORESTS

So much for land with too much water. Now for land with not enough water. A recent survey of the arid and semi-arid lands of the United States, conducted by the federal government, placed the total at 1,160,000,000 acres. Compare this with the total land area of the United States, 1,937,000,000. View this comparison in the light of the knowledge that the prosperity of our great food reservoir in the Middle West depends on a rainfall of not less than thirty-five inches of rain a year.

Arid land means less than ten inches a year. Semi-arid land means less than twenty. Our dominions shrink considerably when we put the foot-rule of available rain-fall on them, regardless of whether or not the nature of the soil and the topography permit agriculture.

Nine per cent. of the area of continental United States has less than 10 inches of rain; thirty per cent. less than 20 inches and more than 10 inches; thirty-three per cent. between 20 and 40 inches, and twenty-seven per cent. over forty.

Unless the rains fall and the sun shines, all the "isms" and "ologies" of agriculture, both as an art and as a science, go for naught. Rain, or the lack of it, is the constant factor which Jeremiah the Gleaner must keep in mind when he is charting his empire of opportunity. It was not the Rocky Mountains that stopped the westward tide of immigration. Immigration stopped at the ninety-ninth meridian, less than half the distance across the continent—and rolled back on corn-belt acres, not because there was not land enough—but because there was not water enough.

Between the ninety-ninth meridian and the Rocky Mountains there is a strip of level table-land three hundred miles wide, the Great Plains—clean enough, smooth enough, rich enough to feed the nation for generations to come. Except for one fact—it hasn't enough water. It is water in the long run that will

determine how much of the nineteen hundred million acres of our realm will eventually go under the plow.

A loaf of bread, one pound of bread, costs two tons of water in the making.

A pound of beef requires from fifteen to twenty tons.

A ton of hay pumps five hundred tons of water out of the soil before it is ripe for harvest.

The food required by one adult human being in one year represents the "water duty" of five acre-feet—an acre of water five feet deep—one million and a half gallons. This calculation (Year Book Department of Agriculture, 1910) is based on the assumption that one thousand parts of water are required to produce one part of dry matter. Plants drink their food in dilute solutions and exhale the moisture into the air in the process. The prosperity of the Middle West requires a thirty-five inch rainfall annually. Was it a mere coincidence that the two great panics of recent years, 1873 and 1893, followed periods of prolonged drought throughout the Middle West?

An accident of Nature ages gone by, a

gigantic cataclysm of past geologic times powerful enough to pile granite and quartz three miles high in the air, raised the Rocky Mountains as a wall on the west against the passage of the moisture-laden winds of the Pacific Ocean. The sudden cooling of the humid air currents which have drunk their fill in their race over the waves robs them of their moisture as they rise high to ride over the range of hills and mountains. In southern California the razor-like peaks of the high Sierras account for the almost tropical luxuriance of vegetation on the windward slope of the mountains and the barren desert sand to the leeward; yet these two regions lie parallel to each other and seem separated by little more than a stone's throw. The Sierras crowd the ocean closely on the south. To the north, where the Cascade Range sets farther back from the tide, a strip of well-watered fertile country more than one hundred miles wide in places extends northward through California, Oregon and Washington.

But once one has topped the summit of the rock-ribbed back-bone of the mountains of the Pacific States, a stretch of nearly fifteen hundred miles of ill-nourished land lies before him

toward the east. Here and there a vagrant rain cloud finds its way in and out among mountain passes, to bring peace and plenty to some well-favored valley, and occasional pockets among the high hills are fed by melting snow drawn from wide areas.

It is among these inter-mountain valleys that the Gleaners have sought to impound the scant waters that fall from the heavens and make the land fertile by irrigation. It is roughly estimated that less than ten per cent. of the continent included in the geographical divisions known as the Far Western and the Pacific States is susceptible to agriculture of any type. Not because of lack of land, but because of lack of water. So scant is the water supply that government engineers agree, when the last ditch has been dug, less than fifty million acres will have been added to the cultivated land of the nation by means of irrigation. The engineers have been paring down their estimates for many years. In the beginning it was believed that over one hundred and twenty-five million acres could be reclaimed by water. In fact, the land area susceptible to irrigation aggregates a total considerably greater than that figure. But the

water will run out long before the available supply of land and the residue is of questionable value even under the most refined of dry-farming methods.

There is an interesting parallel between the land with too much water which we are reclaiming by drainage and the land with not enough water which we are reclaiming by irrigation. The swamps lying at low levels are fertile beyond the ordinary, once drained, because for ages they have drawn on the alluvium of the neighboring prairies. Just so, the irrigated valleys of the Far West are fertile because for the most part they consist of pockets of silt deposited by the erosion of centuries. And, just as the swamp lands we are reclaiming by pumping systems need never feel the blight of drought by judicious management, so the irrigated lands are held at their maximum degree of productiveness by regulation of the amount of water turned over them. With drained lands the source of water supply is constant and independent of the heavens through seepage, and on irrigated lands the optimum moisture content is merely a matter of turning on or off the gates. In this respect alone the Gleaners are able to

compete at better than even terms with the Reapers who have gone before them.

Both the federal government and the various states have spent large sums in encouraging and establishing irrigation enterprises, and, in all projects in which they have lent a hand, it has been with the idea of ultimately making them coöperative. Yet, in spite of official subsidy in irrigation as in drainage projects, less than sixteen per cent. of the total fourteen million acres irrigated in 1910 was due to federal or state aid. The bulk, about eighty-four per cent. of the whole, had been constructed by individual, coöperative or commercial enterprise.

Irrigation, then, will finally add about fifty million acres to the area of improved farm land. This means another state, a trifle larger than the State of New York. Although irrigation was the first phase of the reclamation movement to get under way, it showed signs of lagging about the time of the last census, because of over-development. "Ditch" farming presents new and intricate problems to the farmers who elect to glean by that method and requires intensive methods and corresponding large outlay of capital. This is one explana-

tion of the fact that the census enumerators of 1910 found nearly six million acres of land ditched, diked and graded, and with water waiting, still unoccupied. Another explanation of this over-development which amounted to nearly thirty-three per cent. of the whole lay in the fact that a large bulk of irrigable land was in the hands of commercial enterprises, held at higher rates of valuation than the prospective settlers were able to command.

Between the 99th and the 104th meridians lies the Great Plains area, comprising nearly three hundred million acres of bench lands, for the most part occupying an altitude too high to be watered artificially even were there water enough for the purpose. It was over this region that the last tide of home-seekers spread to the extent of forty million acres in the ten years ending 1910. They must look solely to the heavens for succor as must those in the Great Basin lying in the inter-mountain regions where irrigation is not feasible.

Broadly speaking, dry-farming is confined to those lands which cannot be profitably irrigated, which receive an annual rainfall of between ten and twenty inches. However, there

are so many factors making for success or failure for the Gleaner who casts his lot with the settlers of the semi-arid plains that the mere statement of ten or twenty inches of rain means little in selecting a homestead. As we have already seen, evaporation plays an important part, being less rapid toward the north, and therefore making the inevitable task of conserving moisture more simple for the farmer of the Dakotas than for the farmer in Texas.

Referring to this important factor in determining the ultimate availability of the dry lands, Lyman J. Briggs sums up as follows (Bulletin 188, Bureau of Plant Industry, a monograph on dry farming in relation to rainfall and evaporation):

"Dr. H. L. Shantz, of the Bureau of Plant Industry, finds that the distribution of native grasses is a good index of the rainfall requirements in the different sections of the Great Plains. Short grass, which consists chiefly of buffalo grass and grama grass, is well suited for this purpose since it occurs from Montana to Texas. In each section the grass grows as far west as the opposing influences of rainfall and evaporation will permit. The growth of this short grass in the east is

checked by competition with the prairie grasses. Thus we have a strip of short grass extending from Montana to Texas limited on the west by drought and on the east by competition with other grasses. Therefore the increase in the annual rainfall as we go from north to south in the short-grass region represents the additional amount of rain needed to offset the increased evaporation. In Montana short grasses unmixed with other grasses occur in districts having an annual rainfall of approximately 14 inches; in Colorado in regions having rainfall of 17 inches, and in the Panhandle of Texas in regions having an annual rainfall of 21 inches.

"The same type of grass requires in Texas 7 inches more of rain a year than in Montana. This gives us at once a measure of the additional amount of rain required for a grain crop in Texas as compared with Montana. * * * * A rainfall of 21 inches in the Panhandle of Texas is therefore really no better for growing crops than 15 inches in Montana or Dakota."

Another and still more important factor is that of seasonal rainfall. The seasonal distribution of rainfall in the semi-arid lands is divided into three types—the summer rainfall of the Great Plains region; the winter and

spring rainfall of the Inter-mountain region, and the winter rainfall of the Pacific region. Three-fourths of the total rainfall in the Great Plains region occurs during the six months from April to September. On the Pacific Coast, on the other hand, the rainfall occurs almost entirely during the winter months, and the summers are dry. In the Inter-mountain region the bulk of the rain falls during the late winter and early spring. This factor needs must affect both the nature of the crops grown and the method of cultivation. In the Great Basin land must be kept under clean summer fallow and a fall-sown crop is then able to take advantage of later winter and early spring rains. ("Dry Farming in Relation to Rainfall and Evaporation," by Lyman J. Briggs, Bulletin 188, Bureau of Plant Industry.) On the other hand, the summer rains of the Great Plains region and the excessive evaporation make summer fallow expensive, and the land is usually cropped year in and year out. This government, as well as Canada, has recognized the necessity of large individual holdings in these regions and both in our own West and on the western prairies of Canada the new settler is urged

to adopt 320 acres instead of the usual 160 acres or quarter-section as his unit.

As previously stated, less than twenty per cent. of the Great Plains and Great Basin area of our West will ever come permanently under the plow, and those farmers who will persist and succeed against the adverse conditions will be those who farm large areas by systems requiring the least expenditure of labor. In the beginning the settlers in the Far West discovered that their returns did not depend upon the amount of labor they expended. Once they decided on the nature of their crops and the system of cultivation their profits or losses depended solely on whether the season's rainfall was above or below normal.

"The people of this region are not shiftless," says Mr. E. G. Montgomery, of the Lincoln (Neb.) Experiment Station (Dry Farming Congress, Manhattan, Kansas, June 26, 1907), "but are practical and optimistic and deserve some credit for their ability to adapt their methods of cultivation to a climate of this nature and be able to succeed as well as they do. The principle in most of the farming seems to be to put as little expense as possible into the farming of an acre of ground on the theory

that if it rains a good crop will be produced and if it does not rain nothing will be produced under any conditions. This enables them to farm extensively and to cultivate the land at from one-third to one-half as much expense as in eastern Nebraska; hence if they secure a crop one-half or one-third the time it is produced almost as cheaply as a crop in eastern Nebraska. Their cheaper cultivation is due partly to the fact that the weeds are less troublesome and partly to the fact owing to the drier seasons that the soil is kept in good tilth much cheaper. However, this should not be too encouraging because there are many disadvantages connected with securing a crop only once in every two or three years even though it may be produced as cheaply as a crop every year."

It is this factor in the situation that has given rise during the last few years to the "jumbo" wheat ranches in the Dakotas, where it is not uncommon to find tracts of five, ten, or even twenty thousand acres seeded down at one time. For, just as we have seen in another phase of Gleaning, draining of swamps, it is more economical to drain ten thousand acres at a time than one hundred, so

by extensive methods wheat fields covering whole townships are better business than wheat fields of forty, eighty, or one hundred and sixty acres. In response to this movement the Far West has produced its own peculiar type of machinery. Machines which "head" the grain (leaving the straw standing), thresh it, winnow it and pack and deliver it in bags at one operation in the field have come into general use wherever the acreage justifies the expense, and gasoline tractors which at once plow, harrow, seed and cover (with electric searchlights which light the task for twenty-four hours a day during the seeding time) are no longer curiosities to the broad-gauge farmers of the Great Plains.

The soil itself is intensely fertile and responds sensationally to favorable seasons of rainfall. Witness, in 1907, spring-plowed land at the experiment station at Edgeley, N. D., produced 4 bushels of wheat an acre with 7 inches of rain during the growing season; in 1908, 13 bushels with 9 inches of rain, and in 1909, with 11 inches of rain, the yield was 28 bushels. The elements of gamble are always present. A normal rainfall in many districts produces returns sufficient to make amends for

several bad seasons and pay handsomely out of balance for the bounteous season. Five years of drought may depopulate vast townships whither high hopes had led an army of settlers, and five years of normal precipitation are just as apt to transform the humble "nester" into a capitalist far beyond the dreams of his more-favored prairie brother. Nevertheless, the capital required to bridge the uncertainty of the heavens tends toward a more and more extensive scale of cultivation.

For the small farmer who must be content with random cultivation of his 320 acre homestead, it is evident that something more material than the possibility of one crop every two or three years must be held out as encouragement. Rainfall does not follow the plow except in the poetry of forlorn hope, and since there is no way of bringing the optimum amount of water to this otherwise fertile land, the only solution of the problem lies in the introduction of drought-resisting cereals, grasses and fruits.

The search for, and acclimatization of drought-resistant crops has, in fact, constituted the most important work of the Depart-

ment of Agriculture at Washington for the last several decades. There is a Darwinism among plants as among animals. The fittest survive to form individual races. Somewhere in the world an isolated plant has lived and thrived among the very adverse conditions which have meant death to millions of its kind, and it is these isolated few that are being sought continually by a small army of plant scouts who scour the world in their search. The interior of China, Northern Corea and the steppes of Siberia present conditions similar to those to be found in the Great Plains regions—high, wind-swept plateaus and arid plains.

Upward of $50,000 a year is now being spent on exploration for crops suited to the peculiar conditions of cold and drought to render productive a vast region that otherwise would continue to produce only bunch grass—and that so sparsely that to graze one rangey steer requires between twenty-five and fifty acres. Alfalfas from Siberia and Turkestan, the non-saccharine sorghums, Kafir corn, stone fruits, the Chinese jujubes, dry-land poplars, willows and apricots and date-palms are conquering arid acres. Recently the rare date,

the Deglet Noor, was introduced from Africa and planted to orchards in the arid deserts of Arizona. The plant, which had developed a remarkable drought-resisting quality in its native soil, seemed destined to failure as an American product. In its new home it produced handsome fruit, yet wholly lacking in the wonderful flavor to be found in the same variety in Northern Africa. Specialists of the Department of Agriculture set about to solve the difficulty and discovered that the flavor of the Deglet Noor was due to a fermentation which occurred at maturity. This fermentation required a sustained heat of 104 degrees for several days. Its native climate favored this development. No so, however, its new home. The difficulty was solved in an unique way. The ripe fruit from Arizona trees was picked and literally "hatched" in ordinary chicken incubators. This simple fact, once discovered, has resulted in thousands of acres of otherwise useless land becoming of economic importance.

Several years ago the long-lost manuscripts of the Austrian monk, Johann Mendel, were found. The monk gave his life to the culture of sweet peas and set down his observations

with the insight and clarity of genius. To-day he is ranked with de Vries and Darwin, because of the new hypothesis he developed. He established the fact that some of the characters of both plants and animals are inherited unchanged, passing down through each subsequent generation. Many of these dominant characteristics may be hidden in the first generation and in a fraction of the descendants of each subsequent generation. But these dominant characteristics appear in pure form in part of each generation after the first, so that the descendants of two parents, both showing the same trait, will continue to perpetuate it.

How does the Mendelian theory apply to the extension of the floor space of the American farmer?

Thus—a bushel of wheat represents thousands of characteristics of cross breeding. In one branch of the complex ancestry there may have been a strain of wheat with the characteristic of germinating at low temperature. If such were the fact, the discovery of this characteristic among a dozen or a hundred grains of the thousands composing the bushel would enable botanists to revive the lost strain.

The economic importance of such a trifling fact can be measured by the thousands of acres in the semi-arid West where a cold spring precludes wheat from taking advantage of a favorable seasonal rainfall. A wheat adapted to such adverse conditions is exactly what the experts sought, and, having found by a simple process, began breeding. To find this strain they held the temperature of mechanical germinators ten or fifteen degrees below normal. Ordinary wheat would not germinate at this temperature. But, among the thousands of grains put to the test, possibly ten are found to sprout and grow. These ten, isolated and propagated, form the nucleus of a re-incarnated race.

The sifting process can be carried on indefinitely by varying the conditions under which the seeds are sprouted or grown. Durum wheat, introduced in Kansas by the Mennonites from Russia, is merely an example of the process, a pure-blooded strain with dominant characteristics well defined. It is worth forty million dollars a year to the farmers of the Great Plains. The non-saccharine sorghums, brought from China at a cost of less than $2,000, account for another forty millions

of gross returns in the same region, and Kafir corn produces fifteen million dollars a year in the Far West.

It is apparent from a consideration of the factors affecting agriculture in the Far West that the problem is not merely one of additional expansion, but principally to hold what ground has already been gained. Witness the retreat of settlers from thirteen million acres in southwestern Texas in the ten years ending 1910. Even when the prospective settler is in possession of the last word on seasonal rainfall and temperature and high winds (which any day may pick up his summer-fallowed field and lift it over the fence as a present to his neighbor), when he is in possession of official advice as to what highly specialized crops to plant and how to plant and cultivate them, yet he is still as much in the dark concerning the capacity of his own particular acre of half-section as an individual who seeks to determine how long he will live by consulting an actuary's table.

Every influence making for good or bad in this region of scant rain is an individual problem to each acre. The one rainfall of a season may be so torrential in its downpour

as to cause an excessive run-off before the thirsty soil can drink it up and hold it. It is not an uncommon experience for rain storms to be so clear cut in their path as to divide a dusty road in two parts. Differences in annual rainfall, not for one year only, but extending over twenty years of observation, are found to exist in almost the same startling measure between adjoining townships. Quoting again from Bulletin No. 188, Bureau of Plant Industry:

"The rainfall in the district around Aberdeen, South Dakota, is nearly 5 inches above that of surrounding sections. This difference is based on observations of twenty years or more, and the effect on crops is so marked that the farmers generally recognize that good crops may be found in this section when the surrounding regions are suffering from drought. It is important then to have as many rainfall stations as possible to measure accurately the annual precipitation."

Upward of sixty million acres are under cultivation by dry-farming methods in the Great Plains and Great Basin regions, and it is the opinion of those who have given their lives to the solution of the problem of more

cheap land that this acreage will never be materially increased. In fact, many believe that the western fringe of the dry-farming region is destined to revert to grazing. The systems of cultivation under which the region is now being exploited do not make for the conservation of soil fertility. Conservation of moisture is the main problem. As we shall see in subsequent chapters, single-cropping and extensive agriculture go hand in hand, and experience has shown that our prairies toward the east, stuffed with decaying mold of hundreds and hundreds of years of prairie grasses, were broken down in a generation of such exploitation. The immediate problem of raising crops is so pressing that we have not yet given heed to the ultimate fate of these lands under the systems which are found most profitable for the day.

At one time, geologists tell us, the Great Plains were well watered and wooded. Only recently remains of prehistoric cities have been uncovered in western Kansas. A great need of the present day is windbreaks of trees to prevent the blowing of soils, a factor which is extremely serious in many sections, and plant scouts are seeking dry-land trees. An ex-

periment station has been established at Mandan, North Dakota, to try out the imported varieties, that the Great Plains may again be wooded. What became of the forests that once covered the region is one of the baffling mysteries which scientists have not solved.

As to the former fertility of the bench lands, it is at least partially explained by the fact that at one time the waters of the present Gulf of Mexico extended as far north as the confluence of the Mississippi and the Missouri Rivers; the land of cotton extending south of this point at the present time having been built by deposits of alluvium during subsequent periods. An upheaval, resulting in the formation of plateaus and mountains in the Southwest, causes the moisture-laden winds of the Gulf at the present day to veer to the north; otherwise the Great Plains would today be a land of rain and the fertile bottoms of the Mississippi River valley would be struggling with the problems of dry-land agriculture.

Soil fertility depends not only on the mineral elements in the soil, but equally upon complex organic compounds, the result of decaying vegetable matter. The reserve fer-

tility of the Great Plains regions with sufficient water undoubtedly dates back to its early history. How long an exploitive system of farming, where fallow is the only "fertilizer" and the only organic matter returned to the soil is the dry stalks of grain, can remain on its own feet is a question another generation will have to answer. At the present time it seems that a sufficiency of water alone can solve the problem. The Chinese, who have been farming for more than forty centuries, and are many hundred years ahead of the rest of the world in efficiency, solve the problem of water by turning back their rivers from the sea by means of lateral canals. Their acres are forced to grow not one, but several crops each year; and what a western nation would consider a sufficiency of water is inadequate in China. It is for this reason principally, and to provide transportation incidentally, that conservation has reached a point in China where every gallon of river water that escapes to the sea is considered just so much potential fertility lost.

Is it not possible then, conceivable at least as a dream of the distant future, that the United States will some day arrive at a point

where it will become a public function to divert the excessive rainfall of the East to the arid regions of the West by means of grand trans-continental canals? The surplus water of the 77,000,000 acres of swamp alone would be sufficient to restore an equal area in the Great Plains to its prehistoric fertility. And the waters of the Mississippi River floods, which to-day serve no purpose, would, properly diverted by an engineering work not thought possible at the present day, bring peace and plenty to an empire in the Far West as big as France.

To straighten out the tortuous path of the great Mississippi, and confine the riotous spring flood within the walls of a great air-line canal, is already being considered as a possible and highly desirable undertaking by engineers. To impound the surplus water and convey it on a trans-continental journey, raising it stage by stage by means of pumps (part of whose power is furnished by the same water falling in other stages of the same canal), is no greater undertaking than the Panama Canal. Take the map and draw a line along the coastal plain from the swamp regions of northern Louisiana (where the black alluvium

is rendered sterile by shallow lakes for many months every year) westward to the arid Southwest—to Texas, where thirteen million acres of parched soil reverted to bunch grass in ten years because of not enough water. It is not taxing the imagination too far to assume than another billion dollars worth of productive land could be added to the wealth of the nation—and the Panama Canal cost less than one-half that amount. It is a crying need of both the swamp and overflow regions of the South and the semi-arid region of the West, and such an undertaking at least deserves a survey of its possibilities. Dry land with enough water at hand for irrigating purposes frequently touches a valuation of over $2,000 in the arid West. Wet land, with too much water, in the southern states touches $10 in normal seasons and is valueless for the crops suited to its peculiar climate when the super-abundant rainfall exceeds normal. Some day, surely, we must come to learn the story of conservation of water, which the Chinese have practiced for thousands of years.

* * * * *

Vast as is this expanse of land of little rain

lying west of the ninety-ninth meridian, it is the opinion of Dr. Cyril G. Hopkins, of Illinois, and other close students of agricultural economics that the United States of the future will have to look to the "rain-belt" as its main food reservoir. Irrigation in the arid West to-day accounts for less than one-half of one per cent. of the continental area, and dry-farming, as we have said, has arrived at a point of expansion where the problem is more one of holding its own than of further expansion.

The tendency toward concentration of production in the Middle West was already becoming strongly marked at the close of the first decade of the new century.

In the census year of 1910 it was ascertained that fifty-six per cent. of all crops grown was produced in the Middle West. The East, including New England and the Middle Atlantic States, furnished but a fraction over seven per cent. The Mountain and Pacific States, many times more vast in area, produced 6.2 per cent., and the South, 30.6 per cent. Remember in this connection that one-fifth of all the land cultivated south of the Mason and Dixon line is cotton, and that in

the four states of Georgia, Alabama, Mississippi and Texas, over seventy per cent. of the farming produced cotton—not food, but clothing.

Examining the production of food in these grand geographical divisions in another way, let us take the cereals, which occupy forty-eight per cent. of all plowed land in the United States. The acreage in cereals increased only 3.5 per cent. in ten years and the per capita production fell from 58.4 bushels to 49.1 bushels. Is there any reason for wonder, with a population increasing 21 per cent., that the cereal crop of 1909 was worth 79.8 per cent. more in dollars and cents than the same crop in 1899? Such an increase in money returns offered every inducement to the farmer to increase production.

What share of production does the Middle West, the "rain-belt," claim to-day? Of the 1909 crop the Middle West produced 65.8 per cent.—practically two-thirds. The East furnished 4.1; the South, 25.3, and the Far West, 6.2.

The term "rain-belt" and the reservoir of food surplus then become practically synonymous. The problem of rain is not vital east

of the Alleghanies, yet we can dismiss this area as of national importance because it feeds only one mouth in every fourteen. The South is devoted to cotton, and its corn, its next most important crop, is not sufficient to feed the mules that cultivate the cotton. The Mountain and Pacific States, though occupying an area equal to one-half the country, rank in economic importance with New England and the Middle Atlantic States. Thus the farm area producing a surplus of food is narrowed down to a region occupying, so to speak, the solar-plexus of the map. It includes the states of Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa and Missouri, and the eastern half of Oklahoma, Kansas, Nebraska and the Dakotas. It was in this region that settlers, under the Homestead Act, found permanent homes, because of the natural advantages of soil and climate. Every available acre, susceptible to production under the sunshine-and-rain rate of cultivation, was actually producing food in 1910, and it is in this "solar-plexus" of the map that we find farms most highly capitalized on the principle that man is first and foremost a conserver of his own labor and chooses that land

which yields the best returns for the least amount of labor.

It seems almost an anomaly then to find opportunities for the Gleaner in this district. We have already seen that an area of 77,000,000 acres of swamp and overflow lands awaits the Gleaner, and that a goodly percentage of this empire of potential fertility lies in the corn-belt. We have also seen that north of the forty-fifth parallel of latitude in the three states of Michigan, Wisconsin and Minnesota the elemental industry has been not agriculture, but lumbering.

It was not in the scheme of things as we conceived it as a nation in the beginning that this area should remain permanently in forests. Forty million acres in this region has passed into private hands and has been reaped of Nature's first crop. The lumber-jack, fire and the ax have laid the vast area bare, with no thought of reforestation. Because forestry, like agriculture, must be endowed with its plant in the beginning and cannot persist in the end except as a commercial possibility. When the product of an acre of forest is worth only $15 and the cost of reforesting that same acre is in excess of $15, the lumber barons

give no heed of the morrow. As a nation we have recently sequestered some 200,000,000 acres of forests in the Far West and Alaska for the future, but the fringe of hard wood forests that borders the corn-belt on the north must look for its future prosperity to agriculture.

It is in this region that we have already seen four million acres reclaimed from its forest cover in the ten years ending 1910.

Wisconsin alone offers ten million acres for the settler hardy enough to expend from $15 to $50 in labor, in addition to the price of the land (which he must buy), in subduing an acre for the plow. Here in these three states is the original task of the early English in New England, started all over again. With this difference: once the forest cover is cleared the pioneer finds awaiting the plow not the sour, stony hillsides of the East which so set their imprint on the characters of our early ancestors; but, instead, mellow loess, identical in geological origin with the rich loam of the treeless prairies further south—level, deep, and rich in fertility.

And, in addition, the pioneer in these regions finds another factor in his favor. The region

is not a frontier. Forestry and mining have preceded the tiller of the soil; built railroads, huge lake terminals, of which one (Duluth) is second only to New York City in the total tonnage handled, school houses, good roads, churches, manufacturing towns and cities, and, what is of still greater economic significance, a hungry population of 25,000,000 people is within twenty-four hours by rail or steamer. On the north the Great Lakes equalize the temperature to such an extent that the shores of Superior produce in profusion all of the tender fruits and vegetables to be found in the corn-belt. The State of Wisconsin has for many years been considered foremost from the viewpoint of collective effort in advancing its agriculture, yet, after all, until to-day agriculture in Wisconsin has occupied only a small strip toward the south. To-day the State has organized its immigration commission — as have Minnesota and Michigan—and is seeking to attract settlers by a careful survey of the opportunities that lie north of the forty-fifth parallel. The main point that favors its rapid development is that transportation and markets are already at the very door, and, with these factors at hand, who will say that the big

woods acre, cleared of its stumps and mellowed for agriculture, cannot compete on an even basis with the $200 corn belt acre. Here we find raw land as a means of labor in which every unit of effort expended to put it under cultivation manufactures capital for the pioneer.

The State of Wisconsin advises its settlers that forty acres, properly cleared and cultivated, is sufficient for a family. The land is to be had at prices ranging from $5 to $20 an acre, and in many districts so wasteful have been the lumbering systems practiced that cord wood cut from a pioneer's forty-acre tract will repay him for the cost of the land and pay him wages in addition. Pulp mills and brass furnaces stand ready with a market for cord wood and pulp and the expanding railroad industry furnishes a never-ending market for ties.

It is not all prime. Streaks of sand stretch across the three states like bars on a flag and here and there the white heat of fire has taken the life out of the land, to be restored only by infinite pains, time and expense. It is for this reason that the three states comprising the hard-wood belt seek to advise the pro-

spective settlers that they may not be led astray by specious promises.

In this phase of Gleaning, as with drainage and the reclamation of arid and semi-arid lands, coöperation is effecting the most economical results. Just as drainage projects call for engineering feats never before contemplated and as the exploitive farming of the Great Plains regions gives birth to new machinery, so here in the big woods area we find peculiar means and methods. Most primitive of these is sheep grazing in the rich stump pastures, paying returns on the land over the period required to rot out the deep-rooting stumps. With the active exploitation of this district, however, has come its own peculiar machinery, notable among which is the power stump-puller, which operates on the stumps as a dentist is advertised to extract teeth—easily and painlessly. Dynamite and giant-powder are used as well, and where coöperation is the rule whole townships are being rapidly stripped and mellowed. Just as the prairies are rich with the countless generations of molding grasses, so here the stiff clays have been mellowed for ages on ages by decaying leaves and such a range of crops

as tobacco, melons, small fruits and vegetables for canning, and clover, alfalfa, sugar beets and the cereals respond readily to cultivation.

The big woods of the North in the corn-belt region are detailed here merely because they represent in a mass the opportunities of the Gleaner who is electing this means of providing himself with a plant for producing food. The South counts upward of 30,000,000 acres of cut-over forests that can be cleared and worked profitably as farms. The South has been backward in its drainage projects. One does not have to go back of statistics of malaria to ascertain that. Also, the South has been backward in clearing, yet the opportunities it presents to the Gleaner are no less rosy. In the long run it is the price of improved land that must determine the speed with which we set about conquering waste land. So long as it is cheaper to buy prime land than to glean among waste acres, the movement will proceed slowly, and in this regard each township, each county, will measure its own conditions.

By far the most peculiar phase of the movement of reclamation is the tide of immigration that has set in out of the West to the so-

called abandoned areas of the East. East of the Alleghanies one-third of the population is compressed within one-tenth of the area of the country. Nearly eighty per cent. of this population is engaged in manufacturing, is centered in cities—consumers of food, not producers. When the rush of homestead settlers started west in the middle of the last century it drew a vacuum in its wake. The undreamed-of fertility of the great prairies made the clearing of the bleak, inhospitable hills of New England seem like some bitter tragedy. Much land that never should have been reclaimed from its forest cover was permitted to revert to second growth timber, and also much land that had proved fertile—rich river bottom meadows, sunny slopes, and rolling pastures that lay like saddle-blankets across the shoulders of the hills—were abandoned either to their original forest cover or to shiftless, interbred natives without ambition either to follow their brothers west or to preserve the fertile land from the inroads of hard-hack and alders. Transportation and the proximity of markets are tremendous factors in these days when half the population is enumerated as non-producers, dwellers in cities, and it is for this

reason that the abandoned areas of the East have suddenly come into economic importance in the last ten years. Only the tremendous stress of the westward movement of the last fifty years can account for the gross inequalities in the prices at which acres of the East and acres of the West find purchasers. Two hundred dollar land, whose products require a thousand mile haul to be brought to the door of the consumer, is not a rarity in the Middle West. Just so, twenty-five dollar land, with markets at its front gate, is not a rarity in the East. Such a lack of balance can only be explained as a peculiar feature of the period of transition in a rapidly developing industry. It is probable that the greater share of this region east of the Alleghanies will be devoted to growing fruits and vegetables for the city markets. It is here that we find the better class of the recent emigration from southern Europe, seeking to reëstablish themselves in their long-forgotten estate of land owners. Italians, Poles, natives of the Balkans, people who have known land for centuries only as a privileged possession denied to them and valued to its last square meter at the mountain tops, find nothing to

daunt them in the forbidding aspect of a New England rock-ribbed hillside, especially when they can possess it for a few dollars. At home the people of southern Europe are familiar with soil being built on bare rocks, carried in baskets on the backs of groaning peasants. Such made land is common even in the rich Rhine country. Gleaning has been the portion for centuries of these people, and the frugality and thrift, indeed the very low standard of living we profess to despise in them, combine to adapt them admirably for the opportunities they find on every hand in this country.

One in every three of the ten million emigrants from southern Europe who entered our gates in the decade ending 1910 returned home with his savings. In order to accomplish this ambition they lowered even their own low standard of living. They were undesirable aliens in the ultimate extension of the term, and not to be compared with their sturdy, hard-headed brothers, who are willing to sacrifice all for the possession of an acre of productive land. It is this desire to own land that marks what we like to call the American Spirit, and, in the end, must be the factor

which will unify the American race. It is not only the people of Southern Europe who are finding opportunity here now in this age of Gleaning. The hard-wood forests of Wisconsin, Michigan and Minnesota are being cleared by Scandinavians and the Swiss, people who have been imbued with the bitter lessons of centuries in establishing agriculture in their native, ill-favored homes. The history of the communistic settlement of America has never been written. There are Icelandic colonies in North Dakota, Mennonites in Kansas, Dunkards in Saskatchewan, Japanese, Portuguese and Slavs in the Pacific States, and only now an army of ten thousand stalwart, bearded sons of Holland with their families are taking up homes on the border of the Great Plains. These and many others, in addition to the classic examples of the early Puritans in Massachusetts, Swedes in Delaware, Quakers in Pennsylvania, and Mormons in Utah. The early groups sought only communistic isolation. Witness the Mormons as late as 1846 electing to build an empire in the midst of a desert. But the later groups are inspired only by the vision of the possession of an acre of land and an escape

from the intolerable conditions of crowded Europe.

We have enumerated the various phases of gleaning that are under way, and, in the enumeration, have shown how each phase is, in the main, sectional. However, this is true only in a broad way. There is no county, no township in the length and breadth of the country that does not present examples of one or more of these various phases. Drainage and clearing are common to all sections, and the specialization of crops as well. Even irrigation and the best practices of dry-farming are traveling east. New Jersey has come to realize in the last few years that its acres cannot attain their maximum efficiency without irrigation, and the same is true of many other sections of the humid East. Sunshine and rain are the fundamental requisites of agriculture. A soil as fertile as the arid plains is sterile because of lack of water, and the best type of farming must always consider first the conservation of moisture and the elimination of surplus water.

Having considered the reclamation movement, we are now in a position to recapitulate and determine approximately the ultimate do-

main—the floor space of the American farmer—the land actually under cultivation and producing food and clothing.

We have seen that to-day 310,000,000 acres are being plowed. To this we can add 77,000,000 acres to be drained, 100,000,000 acres to be cleared of brush and stones, 35,000,000 acres to be added by additional irrigation enterprises in the West, and lastly, 150,000,000 acres now nominally in farms, but producing nothing but scant pasturage because of lack of drainage, grading, or clearing. That gives us a grand total of 672,000,000 acres.

It is interesting to note, in conclusion, how this estimate of 672,000,000 acres of improved land in the United States compares proportionally with European countries which have long since passed through the period of reclamation, with a single exception of Russia.

The table on the following page shows the comparison at a glance.

In addition to the land actually under the plow, there must always exist as an adjunct to any system of agriculture a considerable area devoted to grazing and wood-lots. The bulk of the Great Plains region, unsuited to any form of farming feasible in the present

PERCENTAGE AND AREA OF ARABLE LAND BY COUNTRIES

Country	Acres	Per Cent. of total land area
United States	672,000,000	36 (est.)
Austria	26,145,000	35.3
Hungary	34,027,000	42.4
Belgium	4,578,000	62.9
Bulgaria	7,352,000	31.1
Denmark	6,402,000	68.1
France	62,726,000	48.0
Germany	63,690,000	47.7
Greece	.....	14.0
Italy	25,056,000	37.4
Netherlands	2,126,000	27.5
Norway	1,019,000	1.3
Portugal	.....	22.4
Roumania	12,602,000	38.8
Russia (Europe)	328,389,000	25.7
Servia	2,999,000	25.1
Spain	.....	35.4
Sweden	8,878,000	8.7
Switzerland	1,681,000	17.0
United Kingdom	18,712,000	24.1

day, will always be valuable as a range for the rough production of sheep and cattle to be "finished" in the feed lots of the East. The present area of 875,000,000 acres nominally in farms includes a great deal of this range country, as well as stubborn fields which never can be subdued for the plow, but will always be of importance as an adjunct to our farming.

Even under the liberal census enumeration of improved acres to-day, only one-half of the land nominally in farms is being cropped. How great this proportion will be eventually can, at the present day, be only approximated. Rough pasture and wood lots probably will eventually represent 500,000,000 acres. By this rough estimate then the ultimate domain of the American Farmer will slightly exceed one billion acres, or fifty per cent. of the land and water area of the country.

CHAPTER V

THE DIVISION OF SOILS AND THE SPECIALIZATION OF CROPS

Side by side with reclamation of waste land we have the task of increasing the efficiency of the individual acre. There is no ethics concerned with the movement. It is wholly commercial. The world must be fed, yet the only means the world at large has of enforcing its demands for food lies in dollars and cents. The more hungry, the greater the price of food, the greater the inducement to the farmer to clear waste land for cultivation or to increase the efficiency of the land he already cultivates. Expediency resolves the equation in the end.

The success of huge industrial combinations depends primarily upon their ability to control production, to attune their output to the popular demand. Nearly seven million farmers are engaged in producing food in the United

States and their output is controlled by many complex factors, among the principal of which are soil, climate, and individual efficiency. So closely must famine follow on the heels of the last harvest to make the business of farming profitable, that the slightest variation of any one of the many factors influencing production in a broad way means success or failure for the individuals. Take a recent instance in the production of corn, our biggest crop. A widespread drought in the fall of 1911 reduced the acreage production from 27 bushels to 24 bushels. The price of corn soared to 62 cents. In the following year the heavens smiled on the land. An acre of corn measured over 29 bushels. Did this spell prosperity for the farmer over his returns of the year before? In the light of the "two blades of grass" theory it should have spelled prosperity. But it did not. The farmer was forced to accept 48 cents for the same bushel that had brought him 14 cents more a year gone by. Actually the American farmer in 1912 was forced to suffer a loss of $40,000,000 over 1911 as a penalty for harvesting an excess of 600,000,000 bushels of corn.

The business of farming is not operated

from a Board room. It is operated in small units by millions of individuals, each of whom must determine for himself what to sow and reap, and stand or fall by his judgment. If an inventive genius were to enable the Steel Corporation to manufacture steel for fifty cents on the dollar the Board of Directors would not manufacture twice as much steel as before on the theory that it cost no more to produce. Instead, they would close down one-half of their plant. Likewise, if an overnight miracle should increase the productiveness of our acres one hundred per cent., one-half of our acres would be forced to shut down by the cataclysm of low prices.

Efficiency of methods and expansion of acreage must therefore follow, hand in hand, the pressure gauge of hunger. The farther we go the more difficult it becomes to expand acreage, because the most refractory waste land will be left to the last. The problem is unique to each individual acre. The Farmer of To-morrow must ask himself, "Will it be more profitable for me to drain a sour swamp or to expend additional capital and labor on land already under cultivation?"

With the end of available arable land in

sight, the problem narrows down to one of efficiency—intensive methods. It is with one phase of this movement that we have to do in this chapter.

We have heard a great deal during the last decade or two of the wonderful productiveness of the older farm lands of western Europe. They are producing two and sometimes three times as much food to the acre as our virgin soil.

Is it merely a question of method, of more intelligence, that the farmer of Holland is able to produce 50 bushels of wheat when the farmer of the Dakotas rarely produces about 12 bushels unless the heavens are especially smiling?

The wheat average for Great Britain is above 32 bushels an acre. The bulk of our immigration previous to the Civil War—and a goodly proportion of it for a considerable period thereafter—was from the British Isles. The immigrants were sons of the soil, had learned farming as an industry in all its branches. England, terrorized by the possibility of a Napoleonic invasion at the beginning of the century, undertook to attain self-sufficiency in the matter of food, and in an-

other fifty years had doubled the productivity of her acres. This was reflected in the individual, the immigrant who came to America and took up his quarter-section of land on the western prairies. Here he found new tools, a soil that had never known the plow. It was easily worked, required a minimum of labor, and the weeds that had become acclimated to the unbroken prairie disappeared with cultivation and did not reappear for another generation.

Yet he did not produce 32 bushels of wheat. Nor 20, nor yet 15, except in bountiful years.

Then came the Germans, the French, the Dutch, and the Scandinavians. The latter must surely know efficiency in farming, since at home a scant eight per cent. of their land is arable.

These are our farmers, these immigrants and their sons and their grandsons. They are for the most part originally from the west of Europe, where pressure of population has denied the working man meat for many years. Germany to-day consumes only 25 pounds of meat per capita—*half a pound a week.*

We introduced machinery such as the European was not to know for decades. In fact,

the peasant of Russia still plows with a crooked stick. We have more schools; the percentage of illiteracy among us is not higher than that of any enlightened European nation. Yet our farmers, drawn from the efficient acres of Europe—they and their descendants—are still producing food at one-third the rate of the European farmer.

What is the answer?

Not in the fertility of the soil itself, surely. The soils of Europe are a thousand years older in point of use than our soils, and—according to the bookkeeping theory of soil fertility—should be near exhaustion. Yet (as we shall see later) a recent comparison (by thousands) of samples of European and American soils failed to reveal any essential difference in physical condition or mineral content.

There is one explanation, that is simple. Look about and find an immigrant recently arrived from western Europe, a farmer by blood and training. Ask him why his father at home is growing 40 or 50 bushels of wheat when he himself is growing 12 or 15 bushels. Is the land any better? No. Has the father better machinery? No; the chances are he has not as good. Is the old-world farmer more

intelligent? No. His son who is here with us has had better educational advantages. Then why is it?

"Because," says the son of the old-world farmer, "my father does not ask his land only if it will grow wheat. He asks it if it will grow wheat better than any other crop. If it would grow barley better than wheat he would grow barley instead of wheat in his rotation. But it happens that this particular corner of his farm grows wheat better than anything else. If I went back home and took some seed corn with me and planted corn where he grows wheat, it might happen that the corn crop would be a failure, even with the best cultivation. My father plants the crop that is best fitted to his own land."

How does he know what crop is best fitted for his land?

His father told him, and his father's father, and so on for many generations. Agriculture is further developed as an art than as a science and always will be. Science cannot tell what crop is best fitted for certain land. But science plus experience can. Knowledge is built on experience, and after a thousand years of experience the old-world farmer has

come to adapt his crop to his land, not his land to the crop.

Tradition—that is the starting point. That is what the emigrant leaves behind him when he comes to this country and raises fifteen bushels instead of forty or fifty. The prairie has already selected its own crop, native grasses. It would be futile for the pioneer turning the sod with his oxen to ask the land what crop it will grow best. There is a market for corn and wheat. Will the land grow corn and wheat? That is all he seeks to know. And the round of a single season answers this question; whereas, according to the Old World methods, it would take hundreds of years to determine what crop is best adapted to the peculiar conditions of soil and climate of each acre. There is the belief that the average soil will produce any staple crop, and it is true in a measure. In any event, in any extensive system of agriculture the secret of the individual acre is not of first importance. It is not until the end of free land, and then of reclaimable land, is in sight that the problem of selective farming becomes vital.

At home the emigrant possessed the secret of each field, handed down from father to son.

In the Old World every farm is a center of learning. Young men in England and on the Continent pay roundly for the privilege of apprenticing themselves to the sons of hundreds of generations of farming, though the secrets they learn do not extend beyond the limits of a square mile or a county. They do not matriculate for long courses of study in meteorology, chemistry, bacteriology, etc., which a younger people would study to get at the same end by deductive means. Your Old World farmer, who is so often held up to laugh the American farmer to scorn, is not a "scientific farmer," as we have come to use the term. If at home the emigrant practiced the same promiscuous agriculture that he must needs practice in a pioneer land, he would get the same returns as Jeremiah. It is not ethics, it is purely business. The farmers of western Europe have land that will not grow more than 10 or 15 bushels of wheat to the acre. They do not grow wheat on these acres because it does not pay. Other crops pay better.

England has been farming practically the same acreage area since 1350, although her recent tax laws have caused some additional land to be thrown into cultivation. That

means she has been using the same tools for that length of time. The Teuton has been at it for a thousand years, and China has been at it so much longer that she has learned by experience, not by laboratory science, that pork is the most economical meat because the hog is the most efficient machine among meat animals.

Here we have the starting point of efficiency. It is not working the acre harder. It is working the acre under the most favorable conditions, along the line of least resistance. Division of labor is as economical among acres as among human beings. The appearance of the term "corn-belt" is a symptom of the gradual movement toward the specialization of crops. Corn originated in Central America and gradually worked north until at length we believe it has found its most favorable environment in what we term the corn-belt. Very simple influences may determine the confines of a crop zone. As, for instance, wheat requires a period of dry weather for curing at the same time in the year when corn requires moisture for the best development of its stalk. The Department of Agriculture is deluged with requests for information by farmers.

Why, they ask, will my land not grow wheat, when it grows corn to perfection, or vice versa? They invariably send samples of soil as the key to the riddle. Here it is not a question of soil, but of climate, seasonal rainfall. Large areas in the Great Plains regions are susceptible to winter wheat culture, when spring wheat would prove an absolute failure, and vice versa, merely because of this factor of seasonal rainfall. But the pioneer in those sections cannot answer those questions for himself until he is in possession of all the facts affecting his acre. As the American farmer gradually comes into possession of this knowledge, and applies it, the productiveness of his acres automatically increases without a corresponding increase in the expenditure of labor and capital.

The first consideration determining the proper agricultural use of soils is climate.

Professor Milton Whitney, chief of the Bureau of Soils, Department of Agriculture, sums up this factor as follows (Bulletin 55, Bureau of Soils):

"The climate of continental United States varies greatly, probably much more than is generally realized. In the southwest we have

the semi-tropical arid climate. In Southern Florida we have the semi-tropical humid climate. Over the country as a whole we have from more than 60 inches to less than 10 inches of rainfall and a range in mean temperature of more than 70 degrees F. to less than 40 degrees F. The elevation of our arable lands varies from below sea level to 6,000 feet above. We also have varying types of rainfall; the greatest precipitation may occur in the winter months or may come in the summer months. We have the greatest differences in relative humidity and sunshine. We have differences in the range of temperature both seasonal and daily, and we have differences in the length of the growing season. Finally we have differences due to slope, exposure, large bodies of water, and other influences too subtle for us to measure, which may determine the special fitness of the soil for a particular grade or quality of product."

He shows that with variations of rainfall with intervals of 10 inches and variations of temperature with intervals of 5 degrees we have forty-six combinations of these two factors alone, which may affect crop development and influence the utilization of soils. He proceeds:

"While it is not possible as yet to give an expression to meteorological data which will be a sufficient guide to crop characteristics, it is possible, by a careful observation of crops and native vegetation, to form a very accurate estimate of crop possibilities and to define areas in which certain crops having certain qualities may be produced. Such an area as the tobacco area of the Connecticut Valley is a case in point; also areas producing sugar beets, sweet corn and some varieties of fruits. There are special localities where grapes are known to do especially well. The Albemarle pippin, which grows best on one particular soil, takes on its brightest color only when grown on this soil in sheltered coves between certain elevations in the Blue Ridge Mountains.

"The differences in climate not only affect the plant directly, but have great effect upon the soil and its chemical properties or composition—particularly in regard to the chemistry of its organic constituents—making the soil to this extent a different soil and thus affecting the plant."

Science unaided cannot solve the problem of specializing our acres. China and Europe have depended mainly on tradition—experience. We are combining the two means to the same end, and, as a result, have set about

to acquire a knowledge in the course of a generation that has required hundreds of years in the older countries.

This task is being carried out by the Bureau of Soils in Washington. It is the intention, figuratively at least, to make a card-index of our acres; quite a task when we consider that nearly a billion acres are nominally in farms. In this work the Bureau of Soils is aided by the previous work of the Geological Survey as to the geological origin of soils, and by the Weather Bureau as to meteorological conditions.

First comes the grand classification of soil provinces in the light of geological formation. Thus we have a map representing the result of a detailed survey of over 106 million acres of farm lands up to the year 1911 representing provinces derived from various agencies, among the most important of which are the disintegration of old crystalline and metamorphic rocks, glacial action, the sediment of rivers, the washing of waves and tides, the residue of lakes and the retreating ocean, wind attrition, heat metamorphism, volcanic action, etc. There are in all thirteen great soil provinces, differing from each other both as to the

original material and as to the dominant agencies operating in the formation of the soils themselves.

These in turn have been subdivided primarily into more than seven hundred soil types, beyond which the subdivisions are almost infinite in number.

For the reader who is interested in the technical as well as practical discussion of this subject in detail, Bulletin 78, Bureau of Soils, "The Use of Soils East of the Great Plains Region," is available through the Department of Agriculture; and separate pamphlets describing each soil type are being issued as the work progresses.

This is pure science. What is its practical application to the economics of American agriculture? How does it affect the fortunes of the Farmer of To-morrow?

By the aid of pure science we are manufacturing tradition—the tool of the European farmer—in pill form, so to speak. We do not stop with the classification of soils according to geology and meteorology. At this point the investigation would be without value to the man behind the plow. When the soil experts bore a three-foot hole in an acre and assay

it critically according to text-book methods, they know something about that soil that the curious farmer does not know.

But he in turn has facts they desire. What did he plant on this acre last year, the year before, ten years ago? Did wheat pay better than rye? Did corn pay better than potatoes? What of his rotations? Here we are getting the testimony of the experiences of one man. The experts go to his neighbor; to a man in the next county who is plowing the same type of soil; to a man in the next state, or ten states away. Here are hundreds of testimonials which can be resolved into means and extremes, the tradition of the Old World farmer rolled into a handy unit. We are not waiting a hundred or a thousand years. When a soil type has been examined thus in all of its details, the Bureau of Soils is able to say to the farmer what type of farming is best suited to his peculiar acre.

And thus gradually (for the mass moves slowly, especially when advice is printed in books) we are coming to an intimate knowledge of the individual acres, which will enable the Farmer of To-morrow to increase the productiveness of his land without a correspond-

ing increase in the expenditure of capital and labor. It is entirely aside from cultural methods, good seed, and the other factors. It is a secret available to the slovenly as well as the most scientific farmer. All of this information must be made use of in the light of markets—cash return—otherwise it is valueless. But gradually crop specialization is becoming more and more sharply defined. In its grand divisions it is already becoming perceptible. The Dakotas produce more wheat than the Mountain and Pacific States combined; Minnesota outranks the entire country east of the Alleghanies and south of the Ohio River in the same sphere. The single state of Iowa produces thirty times more corn than the eleven states of the Far West. Illinois and Iowa have abandoned wheat culture for corn and cattle feeding; California likewise has abandoned wheat for citrus fruits.

It is not merely a random accident that Kentucky thoroughbreds come from Kentucky, unless indeed the accident is traced back to the geological epoch when a stratum of limestone was deposited in the Ohio River valley. To illustrate the refined use of soils,

let us quote again from Bulletin 55, Bureau of Soils:

"The peculiar adaptation of soils to special crops has long been recognized. Nowhere is this more strikingly shown than in greenhouse culture, which, where manures and fertilizers are so intelligently used, is the last place one would expect to find it.

"The hot-house lettuce of Boston has long been esteemed the finest product of the kind received in the New York markets. The soil used in the hot houses is peculiar to the locality. The soil used in the greenhouses of Washington and Alexandria will not produce this fine quality of lettuce, but can and does produce fine violets of rich aroma, and these have the highest reputation in the New York and Philadelphia markets. In general, the roses grown in the greenhouses around New York have the highest rank and are so held in the Boston market, but certain varieties like the American Beauty cannot be produced there in the perfection that is attained in the greenhouses of Philadelphia and Washington. So it goes with any greenhouse crop and with each variety of the crop, the soils of certain localities have certain advantages, small oftentimes, but with so highly specialized an industry, where quality is so important, enough

to give deserved reputation to the locality and to bring better prices to the grower."

"It is coming to be realized that in plant breeding consideration must be given to the character of the soil on which the strains have been produced, as well as to the character of the soil upon which it is proposed to use the selected seed for crop production. Cotton which has been carefully selected until it produces large crops on rich bottom lands will not do so well on sandy uplands. * * * *

"Further, it is quite probable that some of the soils which we count as unproductive and unsuited to our staple crops, or where the expense of putting them in condition for good yields would not at this time be justified, may be found to be particularly adapted for new crops for food, drugs or fiber, or plants might be adapted to them by introduction or breeding. This has been the experience in many notable cases; for example, the utilization of the light sands of the Coastal Plain for truck crops, which only twenty-five or thirty years ago were considered, and indeed were, quite worthless for agricultural crops under the conditions that had prevailed. Also the utilization of the otherwise quite valueless coast prairie lands of Louisiana and Texas for rice culture, when a particular variety of rice, able to stand the peculiar conditions, was found by one of our explorers in Japan."

We have already seen that the introduction of the rare date, the Deglet Noor, seemed destined to failure because a climate, otherwise propitious, in southern Arizona, did not furnish a brief ripening season at the right time. This difficulty was solved by incubation—producing an artificial condition of climate. The truck-growers about Paris have carried this same idea to a point where these farms under glass are capitalized at $10,000 an acre, by transporting soil thousands of miles, and reproducing every particular of temperature and humidity that make for the perfection of special varieties of fruit and vegetables.

Two provinces in little Belgium provide the world with its endive salad; one province in Spain, Almeria, furnishes the world with a Malaga grape that will bear ocean shipment. Corn grown in California differs in its content of proteids and carbohydrates from that grown in Illinois. Long-staple cotton from the Brazos Valley, Texas, transplanted to Egypt becomes a short-staple variety; and emigrant Swiss who thought to transplant a cheese industry to Wisconsin failed utterly, even with their own Swiss cattle, because the hills of Wisconsin could not reproduce the grass of

the alps of Switzerland. Wine and tobacco represent the most refined specialization. The Connecticut Valley is able to reproduce Cuban tobacco by means of tents, and to the observer from the hills the whole valley in the growing season presents the illusion of a vast geometrical lake reflecting dead white to the blue sky. Wine is prized and valued by yearly vintages, the slightest change in weather conditions affecting flavor. California wines are distinctive despite the efforts to reproduce the vintages of the Rhine, Moselle and Burgundy by introducing the vines themselves. The little state of New York has a grape belt as narrow as a ribbon along the shores of Lake Erie; and an alfalfa belt confined to a limestone streak in the north central part of the state. The apples of the irrigated valleys of the Far West are of distinctive size and color, yet they cannot compete in flavor with the apples of Virginia and New England.

Once the nature of the crop best suited to the land is ascertained, the next step is toward the highest refinement of that particular crop. The introduction of plants is one of the oldest activities on the part of the government in its

policy of encouraging agriculture, yet only in the last few years has it come into prominence as a factor of considerable importance. Its sphere is not only to extend agriculture over ill-favored areas that do not respond to ordinary crops and methods, but also to furnish parent stock for breeding strains that will increase the productiveness of fertile acres.

Here primarily is a task for the student, the trained specialist, to test and apply the profound hypotheses accounting for origin of species. The discovery of the long-lost manuscripts of Mendel, the Austrian, thus giving to the world his theory of dominant characteristics, has opened new fields of research. Hugo de Vries, and our native Cyril G. Hopkins, are other individuals whose work is becoming of large significance. It was the theory of Darwin that plants and animals are able to develop individual characteristics only as the result of environment and heredity, and then only over long periods. A deserving thinker who painstakingly cut off the tails of fifty generations of mice, only to find a large and fully developed tail on the fifty-first generation added nothing to the thought of the world, although something to the humor. Yet Dr.

Hopkins was able to prove very simply that he could accomplish results in the cross-breeding of corn, in a single generation, which, according to Darwin should have required many decades of selection and survival. The work of de Vries, Mendel and Hopkins has placed in the hands of the intelligent farmer the means of improving his own seed, developing the particular strain of a given plant best adapted to the peculiar conditions of his land. And once having developed a pedigreed strain its vitality becomes of the utmost concern. The early homesteaders carried their bags of seed west with them, and continued sowing from the same seed year after year. In fact in their penny-pinching economies they frequently saved the culls of their harvest as seed, because of the higher price their grain would bring when sorted and graded. Small wonder that inside of a generation yields in many sections began to fall off, when the short-sighted husbandman sought to perpetuate his prosperity by breeding from the weakest instead of the strongest of his seeds. Not many years ago a rural journal in Iowa sent a student among the Iowa farmers to test the vitality of their seed corn. The investigator

reported the astonishing finding that over fifty per cent. of the seed saved by the farmer for the next planting was sterile. This meant something in dollars and cents to the Iowa farmer. It meant that only two out of the usual four grains to the hill germinated. And the student was able to drive the fact home at this point by still another simple truth that has been learned recently. It is this: Experience in breeding has proved that a large perfect ear of corn selected for breeding purposes is more prepotent when selected from a hill having several healthy stalks than a hill having only one. Why this is true is less important to the farmer in the field than the simple fact that it has been found to be true. It enables him now to select his seed corn at harvest time with regard both to the vigor of the plant and the perfection of the ear; and any farmer who is unable to test the germinating quality of this corn at home can send it to his state experiment station and have it done for him.

Throughout the run of our staple crops, we are beginning to appreciate the importance of the Mendelian theory of dominant characteristics. There are dozens of varieties of

each, well developed in their individuality, to be had for a price by the farmer who seeks to adapt his crop to his soil. Many of them, like certain strains of English oats, are not capable of being propagated on their adopted soil year after year, making it necessary, in order to preserve the characteristics of the strain, to constantly import fresh seed. Plant-breeding has long since passed beyond simple esthetics, although form and color in the flower-garden have developed vital truths to be applied to the economics of agriculture; as witness the life-long toil of Johann Mendel in his Austrian mountain monastery, with his sweet peas.

The adjustment of crops to economic and soil conditions is in its infancy as yet among us. Yet the last census developed the fact that the only state east of the Mississippi River producing enough wheat for home consumption was Delaware. Wheat has been gradually moving west to cheaper lands, until now Minnesota, the two Dakotas, Nebraska and Kansas produce nearly two-thirds of the nation's supply.

Wheat and the small grains are less susceptible than other crops to intensive cultivation. Once they have been provided with carefully

selected soil and seed, the human factor counts for little. For this reason wheat is continually moving toward cheap land where it can be produced on a large scale with a small expenditure of labor. Europe presents a striking illustration of this fact. Mr. Frank R. Rutter of the federal Bureau of Statistics was sent abroad to make a study of the production of cereals in Europe in 1907 and published his findings in the pamphlet, "Cereal Production in Europe." He found that during 1901-1905 the average yield of wheat in northwestern Europe was above 25 bushels; in southwestern Europe, 16 bushels; and in eastern Europe (Russia), 12 bushels.

"It appears, therefore," he says, "that the average yield per acre is highest where wheat culture is less generally practiced, and where the acreage under the grain shows the smallest increase. In other words, the extension of wheat area is most marked where the average yield is lowest. * * *

"That the extent of wheat culture should vary inversely as the average yield per acre, or, in other words, where the results are best, the smallest areas are devoted to wheat, seems at first sight paradoxical. It must be remembered that a high average yield, such as shown

in the Teutonic countries of Europe, presupposes intelligence on the part of the farmers and valuable land justifying a large outlay of capital. These conditions are much more favorable to the growth of crops requiring intensive cultivation than to grain crops which give the highest profit when grown on new land on a large scale."

Thus, it is profitable to grow wheat in western Europe only on the land most highly specialized by nature for its production, because of the high capitalization of land due to the excessive population. It resolves itself into a purely commercial proposition that western Europe looks to the rest of the world for its bread while Russia, struggling with medieval laws and customs, presents an enormous area, its Black Earth Belt, for extensive wheat growing.

Mr. Rutter was able to collect statistics in France to illustrate strikingly this very point. He shows that the returns from an acre in France during the few years preceding 1905 were $153 for hops; tobacco, $93; flax, $72; fresh beans and peas, $62; and hemp $54. The various grains on the other hand averaged only $18, ranging from $21 for wheat to $12 for

buckwheat. Turning to the Netherlands, a land of small holdings, and therefore intensive culture, tobacco returned $213 gross, and grain only $21.

The surplus production of small grains presents a problem for the distant future, especially when we remember that small grains provide three-fifths of our diet. Extensive culture of this most important item of diet must always mark the frontiers; and before us to-day we have the undeveloped Black Earth Belt of Russia, the western plains of Canada and the United States, Brazil, Argentine, Australia, and the unexplored regions in the interior of Africa.

If we turn again to America to seek in what sections the highest type of farming has been developed, as regards specialization of soils, we should naturally decide it was to be found in the East where the land had been under cultivation longest. And this is what we actually do find, in the face of the popular belief that the western prairies are the most fertile intrinsically.

It is the western prairies that produce the surplus through the sheer extent of their

acreage, while it is the isolated and scattered farming areas east of the Alleghanies that present the best acreage returns. A glance at the government crop reports is sufficient to show that in the matter of staple crops the acres devoted to them in the East produce more pro rata than the acres devoted to them in the West. As an example, Maine and Vermont produced 23 and 25 bushels of wheat per acre respectively in 1912, against the national weighted average of 15.9. The same parallel holds good in corn, in which New England generally averaged 45.3 bushels, against 29.2 for the country as a whole.

Land is not more valuable in the East. The price of land and its productive power, as we have seen, have practically driven wheat culture from western Europe. But in our own East we must seek another reason for the more productive acres. That reason is to be found in the fact we have already alluded to in the present chapter. The lands of our East have been under cultivation longer, acreage holdings are smaller, and only those fields—sometimes only an acre or two in extent—are devoted to small grains and corn which have proved themselves, over the course of many

generations, to be the best adapted for such culture.

Up to the present time the line representing productiveness of our acres, taken as a whole, has remained practically stationary, subject in the main only to variations in climatic conditions, both from year to year and from decade to decade. It has followed the sunshine-and-rain rate of production. Isolate New England, however, and we at once have vizualized a sharp upward tendency. The area devoted to farms in New England, however, is too small to affect the national average; just as the wheat production of western Europe, of which we hear so much in the literature of intensive propaganda, does not sensibly affect the production for Europe as a whole. Europe as a whole produces only about 14 bushels to the acre, according to the statistics compiled by Mr. Rutter. And, in addition to specializing her acres, New England is old enough to have developed strains of grain adapted to her acres. Yields of 100 bushels of native flint corn are not uncommon in Connecticut and Massachusetts; and Maine leads the nation in potatoes, with nearly 200 bushels per acre, against a national average

seldom touching 100, and usually around 80 bushels.

Yet the old line farmers have lived to see prime land selling at $25 to $50 an acre in the East, when speculators, still under stress of the western movement, are willing to pay $100 for raw land 300 miles west of Kansas City.

Aside from the problem of soil fertility itself, then, the maximum efficiency of the plant of the American farmer will be attained when the last refractory acre has been reclaimed, and each individual area is devoted to the type of agriculture bringing the maximum returns with an accepted standard of cultural methods —always interpreted in terms of available markets. Many farms produce noxious weeds in terms of highest efficiency as concerns bulk; yet, without a market for weeds as such, the farmer supplants them with some less profuse, but more readily marketable, crop.

As we said in the beginning, ethics does not enter into consideration at all. Farming is a subsidized industry. The nation has presented the farmer with nearly a billion acres as his plant, and capitalized it for him in terms of hunger. It is a fanciful conception to picture the farmer as the trustee of the soil. But

farming is a business which looks neither to its debt to posterity, nor to its debt to our fathers. To establish and maintain its highest proficiency, it can consider only the immediate dollars and cents returns. Beyond that science and intensive propaganda are economic fallacies.

CHAPTER VI

THE BOOKKEEPING THEORY OF SOIL FERTILITY

THE vital question for the Farmer of Tomorrow, however, is not how much land there is, but how much fertility there is in the land that he possesses, or may finally possess. How long, in other words, at a given rate of production, will the soil continue to feed us?

The acres are counted, are definite in number. There never can be any more acres, and, once the last of arable land has been put under the plow, the only means of producing more food is to speed up the machine—to take more out of the soil. That brings us to the most important, and, at the same time, the most perplexing, of the problems confronting the farmer of the future.

How much fertility is there in the soil?

Malthus preached a theory of doom a century ago, and kept all Europe gloomy for

more than fifty years turning over his prophecies. He said that, while population increases in a geometrical progression, the food supply increases in arithmetical progression. Vice, crime and disease slow up the unequal race; nevertheless population must inevitably overtake the food supply at definite periods, and the only means of evening matters again is starvation. It was a mere matter of mathematics. Regardless of how many million acres of unproductive land there existed at that time in the new countries, the day must inevitably arrive when the world would be face to face with the limits of production of its granaries.

Some fifty years after this doctrine went abroad, Baron Justin von Liebig came forward with a theory which seemed to postpone for a time at least the impending catastrophe. He said that crops remove certain ingredients from the soil, but the soil may be made to produce indefinitely, even at a greatly accelerated rate, simply by adding these ingredients in chemical form.

He named these nutrients of which the soil would be despoiled by constant cropping—nitrogen, potash and phosphorus, and showed

how simple it was to mine them, pack them in bags, and scatter them where they were needed for growing crops.

He conceived the soil, figuratively at least, as a medium in which might be mixed, synthetically, all the nutrients required by plants. As a matter of fact this idea is practiced in experimental laboratories at the present day, by growing plants in distilled water, to which have been added the requisite amounts of the different "plant foods" in soluble form.

The world took heart at the announcement of this theory, which seemed to establish the secret of soil fertility by actual field tests. The weight of the name of the great chemist, the greatest of his times, and the seemingly striking verification following the practice of his teachings, caused this theory, the "theory of the mineral requirements of plants," to be generally accepted.

The possibility that the niter beds from which the world derived its agricultural nitrates, and the potash and phosphate mines would prove as limited in extent as the supply of coal or iron or gold began to worry the thinkers in another generation. It was less than ten years after the opening of the present

century that Sir William Crookes arose before the British Association for the Advancement of Science, and, with the authority of one of the greatest scientists of to-day, and the added prestige of being president of the organization he addressed, made the startling prediction that the world must cease growing wheat in another fifty years because of the exhaustion of nitrate beds.

The exhaustion of the world's supply of commercial nitrates is being hastened not only by the demands to feed men, but by the necessity of perfecting devices to kill men. The manufacture of gunpowder and other explosives used in war requires many times as much nitrogen annually as the demands of agriculture, and at the present rate of consumption the end seemed imminent.

So again the bogey of the Malthusian doctrine became a specter and the governments of the world set about surveying and protecting, for their own use, by laws, their supplies of mineral "plant foods." By the beginning of the new century, the new lands of the United States, under cultivation in the main for less than sixty years, were consuming upward of $100,000,000 annually in chemical

fertilization, and yearly the amount was growing, due to the teachings of the officially established federal and state agricultural experiment stations. The nations of western Europe were using even more chemicals for crop production than America. At length economists, whose faith in the theory of ultimate doom is guided solely by the teachings of Liebig, have come to view with chagrin the billions of dollars of food that the American nation has exchanged for gold in the last century, and figure it as so much potential fertility wasted. For gold, exchanged for nitrogen, potash and phosphorus, in the shape of grain and meats, has no nutrient value as food.

Thus Malthus is born again, and, with the passing of free land, the United States has found itself confronted by a cry of exhaustion of the soil. The theory is, in short:

The acreage, the floor space for food consumption, is definite.

The plant food, the innate fertility of the soil, is limited.

The three elements, nitrogen, potash and phosphorus, available as commercial fertilizers, have been blocked out by geological surveys.

And, lastly, the hungry world marches forward in numbers, its appetite increasing in geometrical ratio.

How imminent, or how remote, is the catastrophe, not only of the starvation of a part that the rest may live, but of the starvation of the whole world? Mathematically, one consideration, that of starvation of the whole, is as sound as starvation of a part. Carrying coals to Newcastle is a trite saying, yet the day must inevitably come when coals must be carried to Newcastle before coals can be carried away. Coal and iron, phosphate rock and potash—there is a bottom to every mine.

This is not an illusory hypothesis. It is the accepted theory and practice of the civilized nations of the world, with the single exception of China, where agriculture has been going on for forty centuries; and her acres are still feeding a population fifteen or twenty times as dense as our own, without regard to potash and phosphorus in chemical form.

If this theory is the basis for accepted practice in our agriculture, then surely it should reflect itself, to some extent at least, in the value of land. Dr. Cyril G. Hopkins of the University of Illinois has gone to considerable

pains ("Soil Fertility and Permanent Agriculture") to analyze the resources of the soil of his state and to set down in definite figures how many ordinary crops of corn may be grown before the soil is mined empty. Beyond that time, which he numbers in years encompassing only two or three generations, the soil becomes merely a mixing bowl. It is no longer innately fertile. Ultimately one can imagine it as comparable to the beaker of distilled water in which the scientist of to-day experiments by adding just enough plant food to grow a fixed crop.

If a given acre will cease producing food entirely, or even fall so low in productiveness that the crop does not repay the labor expended thereon, such a condition must affect the value of the land. And, in addition, if, to keep that soil fertile, the husbandman must feed the soil to make it feed him, again the value of the land must be affected. To use a far-fetched illustration, the mines of Newcastle when empty of their virgin coal, and filled again by carrying coals to Newcastle, would be worth the market value of that coal, minus what it cost to buy that coal in the first place plus the cost of transportation. "Salting" a

mine and adding plant food to the soil differ only in degree. One is criminal, while the other is preached officially as scientific and ethical.

The value of a gold mine is appraised, not by the amount of gold that is being taken out of a shaft, but by the reports of a trustworthy body of engineers who have examined the geological formation to which the mine owes its richness, and determined the extent of the lode. Such a mine might produce 5 per cent. net during the first year of its exploitation, and continue to produce at the same rate for twenty years. At the end of its twentieth year it still produces 5 per cent. net, until it is mined of the last ounce of gold it contains. The only way to take more gold out of that mine is to put more gold in. Therefore the shares of that mine are not valued as a 5 per cent. investment in the end, but as assets which have shrunk to 5 per cent. of their original value.

Apply the same principle to the fertility of the land. It is not so far-fetched as it seems at first glance, because we are told that already a large area of our farms has reached a point where artificial fertilizers, "salt," are required,

not only to increase fertility, but even to maintain the fertility that has made these acres valuable heretofore.

When we come to search for parallels to the gold mine example, we actually do not find them in farm valuations, except in the rare instances of naturally unproductive lands. Such instances are so remote from this consideration of the subject that they need not be reckoned with at all. On the other hand, while the rank and file of scientists agree—and here we should accept the rural scientists as we accept the mining engineers—while the rank and file of the orthodox scientists agree that *our farm land is slowly and inevitably declining in native fertility, the price of that same farm land advances steadily.* Land is better as collateral to-day than it was yesterday.

There are coming to be exceptions, it is true—bankers, for instance, who listen to the theory of Liebig and demand that the farmer feed his soil, return to it as much as he takes away, before he can raise a loan with land as security. I have before me now a paper by a banker of the Middle West, who demands such a system. He offers the farmers of his neighborhood loans on their land, providing

they agree to "maintain the fertility of their land" by adding artificial ingredients as plant food for to-morrow. On the other hand here is the paper of another financier, from the Far West, where the fruitful acres are few and isolated and capitalized at a high rate, and worked by the last word in intensive culture—that is, they are being drained of their innate fertility by the speediest methods known to science. This financier seeks farm mortgages on the basis of what the land actually produces. He arrives at his calculation of the value of land by what it produced yesterday and the day before. He does not inquire what it will produce to-morrow. He is willing to let the to-morrow take care of itself. He has faith, in the face of the theory of doom, that if a given acre can be made to produce a certain magnitude of food to-day, it can be made to do the same to-morrow and the next day—and, what is most important to him, at a profitable rate.

The National Conservation Commission was established for the task of taking an inventory of our national possessions, among the most important of which is the fertility of the

land, the resources of the soil for food production. The Geological Survey was able to furnish in definite form the extent of our coal supply in tons, and from these figures it was simple enough to ascertain the remoteness of the day of doom in coal, by dividing the total supply by the estimated annual consumption. They were able to calculate the extent of the national resources in waterpower, measured in feet-per-second of available streams. The Department of Agriculture produced statistics showing that to-day our annual consumption of lumber is forty billion feet and compared this with the annual growth of our forests, showing that if eventually we did not resort to reforestation on a grand scale, we must soon arrive at the end of our supply of timber. They did not concern themselves in this connection with the resources of "plant-food" necessary to grow a definite amount of timber annually. That seemed beside the question. Still, it is readily computed, for we know how much "plant-food" every board-foot of lumber takes from the soil. The mere factor of rain necessary to supply our annual demand for lumber, computed on the equation of 1,000 parts of water for one part of dry

weight, is an important item. While several hundred million acres, rich in every requisite but moisture, are sterile in the Far West, our annual consumption of lumber requires a water-duty of three inches of rain spread out in a blanket that covers the two billion acres of continental United States.

Thus the timber resources were calculated from the extent of the forests and the rate of growth; the water resources from the flow of streams in cubic feet-per-second translated into foot-pounds of energy; and the mines—coal, gold, etc.—by cubic measure estimated by trained geologists and engineers.

The next step was to ascertain, if possible, the extent of the food resources of the nation, as expressed in terms of soil fertility. This question comes nearer home to Jeremiah the Reaper and Jeremiah the Gleaner than any other phase of the inventory of national resources. It has to do, first, with his hunger, then with his pocketbook.

Is the acre, which Jeremiah has mellowed with untold labor, a mine of fertility which he must continually "salt," in proportion as he is successful in applying *scientific* methods for extracting maximum crops? Is it a bank ac-

count, on which every crop is a check marching inevitably toward insolvency, if he fails to return as much food as he takes out? Is it true that after less than two generations of farming we have produced so extensively, taken so much innate fertility out of the soil for home consumption and to satisfy the international balance of trade, that we must now begin to rob Peter to repay Paul?

All that Jeremiah hears, if he listens to the counsel of the official preceptors of his state experiment stations, to the editorials of his rural papers, or to the advice of the man who has chemical plant food to sell, is that the danger of soil exhaustion is not something remote and mythical, like the advance of the polar ice cap toward the equator, but a condition that is actually upon him, threatening starvation for himself and his children.

On the other hand, if he be sufficiently interested or frightened to delve deep into the mountain of literature on the subject, he will find hidden away, discredited by the huge army of preceptors who have grown up since Liebig, a pronunciamento by the Bureau of Soils of the United States government, which says:

The resources of the soil are the one immutable asset of the nation. They can be impaired by abuse, but never destroyed.

If by any chance he encounters this hypothesis, it will only serve to puzzle him the more, so thoroughly soaked is he in the doctrines that have actuated the teachings in agriculture and established the chemical fertilizer industry. The chances, however, are that he has not heard of this theory, or, if he has, that it has been laughed out of his head by his neighbors' sons who are home from college where they received farm training, and anticipate practicing teaching according to Liebig. It was first announced by the United States Department of Agriculture in 1908. We will examine it in detail later. It is sufficient to say now that China, after forty centuries of intensive farming, such as even western Europe does not practice, has not yet learned the use of, or even acknowledged the necessity for chemicals as "plant food."

If, as the accepted hypothesis of soil resources states, the number of crops that can be taken from a given cubic foot of soil can be ascertained mathematically, simply by dividing

the total plant minerals in that cubic foot by the amount of those minerals one crop removes, then the question of the resources of our soils is even more easily computed than the resources of our mines. We have the resources of our coal supply set before us in cubic yards, pounds if you wish.

It is not even necessary, in the light of this hypothesis, to examine all the minerals entering into plant growth. If any one of them is lacking in a given soil, that soil is sterile.

To get at the means that might be employed to strike the balance of soil fertility, we will review briefly the hypothesis of Liebig. He incinerated plants and subjected the ashes to chemical analysis. Plants take their food from the earth, air and water. By burning the plants, he eliminated the factors in plant growth due to air and water, which seemed to him infinite in resource. Thus, in his crucible, he retained only the mineral ingredients. His analysis developed the fact that among the principal elements required in the growth of plants were potash and phosphorus. Among those elements derived from air and water, he considered only nitrogen as fugitive. As the result of his researches he

came to the conclusion that nitrogen, potash and phosphorus were the only elements which were important, as being limited in supply.

To make use of any of its elements of food, a plant must find it present in the soil in *available* form. Upon the meaning of this word "available" hangs the whole of the Liebig hypothesis. It was believed by him, and is taught to-day, that although potash or phosphorus may be present in the soil in great quantities, it is useless to plants unless it is soluble, either through the agency of water alone, or by means of the carbonic acid secreted by the roots of growing plants. The question of immediate soil fertility, then, depended not on how much of a given element was present in the soil, but on whether or not it existed in soluble form.

The natural process of weathering, that is, the action of the natural agencies of heat, cold, sunlight, etc., gradually effected chemical combinations of these soil minerals with bases that rendered them soluble; as do cultivation and the action of decaying organic manures.

In other words, the available mineral elements in the soil are being liberated automatically by natural forces aided by man. As

an illustration, the soil could be likened to a trust fund, of which only the interest was available. If the beneficiary lived faster than his means, he must either put himself in debt, or sit down and wait for more interest to accrue.

Liebig announced that his researches explained the tonic effects on the soil of crop-rotation, a practice which had been established for more than a thousand years before his day. An examination of the ash of plants showed, he said, that certain families of plants require more phosphorus than others, while other families may require a greater percentage of potash or nitrogen.

Thus single cropping might reduce the available nitrogen, potash or phosphorus content of that soil so low as to render the soil infertile for a particular plant. The remedy was obvious. Seed the land to another crop, requiring less of one, and more of the other elements. Thus by a judicious selection, founded both on the facts gleaned from chemical analysis of the ash of plants and on experience, a farmer could arrive at a system of crop-rotation that would render his soil continuously productive, at a certain rate. It was merely

a problem of restoring the balance, giving this or that mineral opportunity to catch up.

The practice of maintaining fertility by means of chemicals is of course the logical sequence of such a theory. If a growing plant has destroyed the balance of the mineral nutrients in the soil, what is more simple than to restore that balance by adding the required nutrients so that all crops may have at all times their optimum amount of "available" food?

The following quotations from Edward B. Voorhees (Fertilizers. Fourth ed., 1902) sets forth the established schools of practice in the use of commercial fertilizers that have grown out of the theories of Liebig:

"*Pages 182-185.*—The one [system of fertilization] which has perhaps received the most attention, doubtless largely because one of the first presented, and in a very attractive manner, is the system advocated by the celebrated French scientist, George Ville. This system, while not to be depended upon absolutely, suggests lines of practice which, under proper restrictions, may be of very great service. In brief, this method assumes that plants may be, so far as their fertilization is concerned, divided into three distinct

groups. One group is specifically benefited by nitrogenous fertilization, the second by phosphatic, and the third by potassic. That is, in each class or group, one element more than any other rules or dominates the growth of that group, and hence each particular element should be applied in excess to the class of plants for which it is a dominant. In this system it is asserted that nitrogen is the dominant ingredient of wheat, rye, oats, barley, meadow grass, and beet crops. Phosphoric acid is the dominant fertilizer ingredient for turnips, Swedes, Indian corn (maize), sorghum and sugar cane; and potash is the dominant or ruling element for peas, beans, clover, vetches, flax and potatoes. It must not be understood that this system advocates only single elements for the others are quite as important up to a certain point, beyond which they do not exercise a controlling influence in the manures for the crops for the three classes. This special or dominating element is used in greater proportion than the others, and if soils are in a high state of cultivation, or have been manured with natural products, as stable manure, they may be used singly to force a maximum growth of the crop. * * *

"Another system which has been urged, notably by German scientists, is based upon the fact that the mineral constituents, phosphoric acid and potash, form fixed compounds

in the soil, and are, therefore, not likely to be leached out, provided the land is continuously cropped. They remain in the soil until used by growing plants, while the nitrogen, on the other hand, since it forms no fixed compounds and is perfectly soluble when in a form useful to plants, is liable to loss from leaching. Furthermore, the mineral elements are relatively cheap, while the nitrogen is relatively expensive, and thus the economical use of this expensive element, nitrogen, is dependent to a large degree upon the abundance of the mineral elements in the soil. It is, therefore, advocated that, for all crops and for all soils that are in a good state of cultivation, a reasonable excess of phosphoric acid and potash be applied, sufficient to more than satisfy the maximum needs of any crop, and that the nitrogen be applied in active forms, as nitrate of ammonia, and in such quantities and at such times as will insure the minimum loss of the element and the maximum development of the plant.

"*Page 186.*—Another system of fertilization is based upon the theory that the different plants should be provided with the essential elements in the proportions in which they exist in the plants, as shown by chemical analysis. Different formulas are therefore recommended for each crop, the constituents of which are so proportionate as to meet its full needs.

This method, if care be taken to supply an abundance of all the necessary constituents, may result in a complete, though perhaps not an economical, feeding of the plant, since it assumes that a plant that contains a larger amount of one constituent than of another requires more of that constituent in a fertilizer than of the others. It does not take into consideration the fact that the plant which contains a larger amount of one element than of another may possess a greater power of acquiring it than one which contains a smaller amount."

But, aside from the possibility of maintaining the fertility of the soil by the addition of chemical nutrients, the question remains, how long will the soil continue to produce crops, by means of its innate fertility? Now, the liberation of available plant food by weathering is comparable to rate of interest on a trust fund in an interest-paying bank only in a measure. A trust fund in a bank is actually at work producing additional capital, which it pays as interest. The trust fund in the soil on the other hand is at work liberating a portion of the capital itself. The statement that the American farmer is "mining" the soil is a familiar one. It comes from this conception

of the nature of available plant food. Every installment of "interest" that the soil liberates in the form of crops draws on its own capital, and when it has run its course the soil is in the condition of the gold mine which continues paying a 5 per cent. dividend until the last ounce of gold is mined.

From this viewpoint the problems of determining the extent of soil fertility should be simple. No matter whether the potash and phosphorus found in the soil are in "available" form or not, they will be available to-morrow or the next day. Sooner or later every gram of plant-feeding minerals would have passed into solution. Then, most truly, would the soil have been "mined" of its fertility, and would possess nothing but a figurative hole in the ground.

It is easy to find out how many grams or parts per million of any one of the "plant foods" exist in a given soil. Take the soil one, two, three, or ten feet deep, according as you believe the plants draw their food. The usual method is to take the first twelve inches of soil and subject it to analysis. Let us examine a series of specimen figures, to illustrate. Hellriegel, a German scientist to whom is at-

tributed the greatest single discovery in agriculture in a century, that of the nitrogen-fixing bacteria of leguminous plants, sampled the fertile alluvium of the upper Rhine in Holland, one of the most fertile soils in the world, and he found it contained elements of plant food as follows, in an acre 12 inches deep and weighing 3,500,000 pounds:

Soluble silicates	81,900 pounds
Lime	143,220
Potash	35,910
Soda	68,920
Ammonia	2,100
Phosphoric acid	16,310
Sulphuric acid	31,360

To produce a crop of barley of 33 bushels to the acre, he calculated, required 55 pounds of potash and 55 pounds of phosphoric acid, with other minerals in proportion. Of nitrogen were required 54 pounds. Then by simple division we find that this richest soil in the world contained enough innate fertility, if liberated by natural agencies, to produce less than 38 full crops if ammonia only is considered, 296 full crops if phosphoric acid is considered, and 653 crops, as to its potash content. This particular soil, it happens, has been cropped for the better part of one thousand

years. The records are fairly complete as to what it has grown in that time. By simple arithmetic, again can we find how rich that soil was in plant food, available and unavailable, a thousand years ago? Apparently we can, if we have faith in the orthodox doctrine of soil fertility.

This brings us back home to the late National Conservation Commission. Analyze our own soils, make a separate analysis for every acre, if necessary. It is no greater task than the Bureau of Soils is undertaking now to determine the cropping qualities of our acres. Take either nitrogen, potash, or phosphoric acid. Not all of them, as any one, particularly the lowest one, will be sufficient. Divide this figure by the mineral requisite of the staple crops grown on that particular soil, and we should have the resources of that soil blocked out as absolutely as the coal in a mine.

But we did not do it. The Bureau of Soils, to whom the question of soil resources was referred by the Commission, happens to be a heretic as concerns the theory of Liebig, though, as we have already hinted, they stand almost alone in their heresy.

Instead, it was suggested that our soils be

examined and compared with the older soils of Europe. The suspicion that our soils were breaking down after two or three generations of cropping, and that the European soils were increasing in productiveness after a thousand years of cropping, was a popular superstition. Surely, if the capacity of the soil is so simple a thing that it can be reduced to fractions, an examination of the older soils of Europe would reveal that fact.

Accordingly, thousands of samples of farm soils were secured from Europe and subjected to analysis. The result is found entire, in Bulletin 57, Bureau of Soils, for any reader who cares to pursue this element of the subject.

A result rather startling to those who believe in the book-keeping theory of soil fertility was forced upon the investigators. *In mineral content (which was the only problem to be solved) they found no appreciable difference between the older soils of Europe and our own.*

Commenting on the results of the researches, Director Milton Whitney said:

"Two points will be mentioned to show the futility of the bookkeeping system of estimating the future resources of the soil.

"The researches of the several experiment stations throughout the world and the investigations of our engineers on the amount of material carried in solution and in suspension in our principal rivers and borne by the wind establish the fact that loss through natural leaching and erosion removes far more mineral plant food elements than do cultivated crops.* In cropping soils, therefore, and removing the crop from the land, we remove an inconsiderable amount of mineral material compared with normal losses to which the soil is adjusted through natural laws.

"The second point opposed to this bookkeeping system of accounting for the plant-food constituents is that in a small majority of analyses reported in this country and abroad, where both soils and subsoils have been examined, the upper soil, from which presumably the roots of annual plants take most of their mineral matter, has a content of potash and phosphoric acid higher than the subsoil.

"From the meager information to be found in the works of the early agricultural writers of Greece and Italy it seems probable that the yields per acre obtained at the present time are not much different from those obtained in the earlier historic times. There are

* The Mississippi River removes enough silt annually to cover 225,000 acres one foot deep.

not many records in the literature of yields per acre for any field, farm, or country going back for any considerable number of years. Official estimates of yields have been kept by the United States Government and many of the States for the past forty years. Similar statistical estimates have been kept by most of the European countries for the past twenty or thirty years. Beyond this the information is fragmentary and possibly less trustworthy.

"In the consideration of data of this kind it would at first sight seem more valuable to have continuous records of successive yields of a single field. However, the yield of a State is probably more reliable in showing changes in productivity because it combines a great number of individual fields and averages the results of all the individual methods used in the community.

"When the yield per acre for a State or country under practically constant acreage is shown to have increased during a long period of years we may assume that the *productivity* has not declined. Much of this increase may result from improved methods of agriculture, better selection of seeds and crops, or the introduction of more live stock; and, for the purpose of our present inquiry, we need go no further to explain the increase or maintenance of productivity.

"There are two matters, however, which

should be considered in this connection. The first is the question of commercial fertilizers. If the productivity of the soil of a State depends ultimately and literally upon our returning an equivalent amount of plant-food constituents to the soil to replace that removed by the crop, then the life of the nation will ultimately depend upon the available deposits of nitrates, phosphates, and potash compounds. It is clearly impossible with the available data to give any expression of the amount of such replacement which has been made in the past, but from what we know, so far as the actual importation of mineral material foreign to the farm is concerned, it is negligible.

"The use of commercial fertilizers is not old. The potash deposits of Germany were first worked in 1862, the phosphate deposits of South Carolina in 1868. Phosphates were discovered in Florida in 1888 and in Tennessee in 1894. It may be said that the general use of commercial fertilizers began in the United States about the year 1865.

"The other matter which should receive attention is the influence of material in the form of foodstuffs imported from less densely settled countries to those of greater population as a possible source of introducing foreign mineral matter to maintain the productivity of the soil of the older and more densely set-

tled countries. If any such transference of mineral material actually takes place to an extent sufficient to maintain or increase the productivity of more densely populated countries, then it is but reasonable to expect that the productivity of the soil of the more recently settled and more sparsely settled countries from which foodstuffs are exported would show a falling off in productivity. From this point of view the soils of the United States might be expected to show some material decline in productivity as a result of the enormous amount of foodstuffs exported, while the soils of Europe, to which these foodstuffs mainly go, should show a corresponding increase."

"The largest average yield of wheat per acre for any one year of the countries abovenamed for the period reported on by the Bureau of Statistics is as follows:

Largest average yield of wheat in different European countries in any year covered by reliable statistics

	Bushels		*Bushels*
Russia	11.4	Switzerland	25.9
Spain	14.9	Sweden	28.0
Italy	15.4	Germany	30.3
Servia	19.4	Netherlands	33.7
Austria	20.2	Belgium	35.1
Hungary	21.8	Great Britain	35.8
France	22.7	Ireland	37.8
Roumania	22.8	Denmark	44.7

"The largest average yield of wheat for any one year in several groups of States in the

United States for forty years, as compiled from the Bureau of Statistics' records, is as follows:

Largest wheat yield in any year for forty years in several groups of States

	Bushels
Virginia, North Carolina, South Carolina, Georgia, and Alabama	11.2
Kentucky and Tennessee	14.3
Texas and Arkansas	15.2
Wisconsin, Michigan, Iowa, and Illinois	16.6
Minnesota, Nebraska, Kansas, and Missouri	16.7
Ohio, West Virginia, and Indiana	17.9
New Jersey, Pennsylvania, Delaware, and Maryland	19.7
California	20.0
Ohio, Indiana, and Illinois	20.2
Oregon	21.1
Maine, New Hampshire, Vermont, and New York	22.4

"It is safe to say that the soils of Europe have been occupied for agricultural purposes for one thousand to two thousand years longer than those of the United States, yet during the past twenty-five years ten out of the sixteen countries of Europe reported upon have produced more wheat per acre than any of the groups of States in the United States during the past forty years."

The National Conservation Commission never went further in its attempt to block out the soil resources of the country. The report of the comparisons of the soils of the United States and those of Europe (4,142 analyses being included in detail) was printed as part

of the general report of the Commission before its untimely end. However, other organizations and individuals have gone further, and for one who cares to figure on our soil resources according to Liebig there is ample material, gathered by competent men.

Dr. Cyril G. Hopkins of Illinois is among those who have reduced the exhaustion of soil fertility to a matter of years. We quote him because of his undoubted position as an educator in the agricultural sciences, and his opinion should carry weight. In addition he is the spokesman of that overwhelming majority among our scientists who stand staunch in their belief that the theory of Liebig is invulnerable, so far as mineral requirements and resources are concerned.

In a recent article (Country Gentleman, Vol. 78, No. 3) he discusses the subject briefly. First he enumerates the important plant foods. Carbon and oxygen, he says, are taken by the plant from the air in the form of carbon dioxide, through the breathing pores, located chiefly on the under side of the leaves. Hydrogen is derived by the plant from the water it absorbs through its roots. These three elements constitute the larger part of the mature

plant (the so-called carbohydrates), and all are constantly being interchanged between the plant and air, or water, in a never-ending cycle of economy.

Iron is a fourth element, "but the amount required by plants is so small, and the amount contained in the soil is so large that soils have never been known to become deficient in iron." Sulphur is used sparingly by plants, frequently merely tolerated. In addition to the supply in the soil, there are constantly being added, by rains and absorption, the sulphurous gases which pass into the air on combustion or decay of organic materials, such as coal, wood, grass, leaves, etc.

To quote from Doctor Hopkins:

"But there are five other essential elements of plant food and these require especial consideration in connection with permanent soil fertility. They are potassium, magnesium, calcium, phosphorus and nitrogen. There are also five important points to be kept in mind in relation to each of these elements: the soil's supply, the crop requirements, the loss by leaching, the methods of liberation, and the means of renewal.

"The neglect of one or more of these important points in relation to one or more of the

five elements has reduced the fertility of most cultivated soils of the United States, has greatly impoverished the older farm lands and brought agricultural abandonment to millions of acres in the original thirteen States. On the other hand, intelligent attention to these same points will bring restoration and high productive power to such lands."

Leaving out of the discussion, for the time being, nitrogen, Doctor Hopkins continues:

"Of the four important mineral elements, potassium is by far the most abundant in common soils. Thus, as an average of ten residual soils from ten different geological formations in the eastern part of the United States, two million pounds of subsurface soil were found to contain: Potassium, 37,860 pounds; magnesium, 14,080 pounds; calcium, 7,810 pounds; phosphorus, 1,100 pounds.

"Even the depleted, and to some extent abandoned, gently undulating upland, 'Leonardtown loam,' which was farmed for generations and which, according to the surveys of the Federal Bureau of Soils, covers 41 per cent. of St. Mary's County, Maryland, and more than 45,000 acres of Prince George's County—still contains in two million pounds of surface soil—corresponding to the plowed soil of an acre about 6 2-3 inches deep: Po-

tassium, 18,500 pounds; magnesium, 3,480 pounds; calcium, 1,000 pounds; phosphorus, 160 pounds.

"The brown silt loam prairie soil of the early Wisconsin glaciation is the most common type of the greatest soil area in the Illinois Corn Belt. Two million pounds of this surface soil contain as an average: Potassium, 36,250 pounds; magnesium, 8,790 pounds; calcium, 11,450 pounds; phosphorus, 1,190 pounds.

"The older gray silt loam prairie, the most extensive soil of Southern Illinois, contains in two million pounds of soil: Potassium, 24,940 pounds; magnesium, 4,690 pounds; calcium, 3,420 pounds; phosphorus, 840 pounds.

"These data represent averages involving hundreds of soil analyses, and they emphasize the fact that normal soils are rich in potassium and poor in phosphorus. This is to be expected, for most soils are made from the earth's crust, and normal soils should bear some relation in composition to the average of the earth's crust, which contains in two million pounds 49,200 pounds of potassium and 2,200 pounds of phosphorus, as shown by the weighted averages of analyses involving about two thousand samples of representative rocks, reported by the United States Geological Survey.

"The plant food required for one acre of wheat yielding 50 bushels, one acre each of

corn and oats yielding 100 bushels, and one acre of clover yielding four tons, includes for the total crops: Potassium, 320 pounds; magnesium, 68 pounds; calcium, 168 pounds; phosphorus, 77 pounds.

"If only the grain, including a yield of 4 bushels an acre of clover seed, is considered, the straw, stalks and hay being returned to the soil—either directly or in farm fertilizer—then the loss per acre from four years of cropping as above would be as follows: Potassium, 51 pounds; magnesium, 16 pounds; calcium, 5 pounds; phosphorus, 42 pounds.

"The average annual loss by leaching from good soils in humid sections is known by the results of many analyses to be about as follows per acre: Potassium, 10 pounds; calcium, 300 pounds; phosphorus, 2 pounds.

"The average annual loss of magnesium in drainage water from good soils is probably 30 pounds or more an acre, but the data thus far secured are inconclusive with respect to that element."

Thus, by arithmetic, it would appear according to these figures that such a soil as the Leonardstown loam would support only two cycles of rotation, or eight years' cropping, so far as its phosphorus in the upper strata is concerned.

The same simple computation can be applied to any particular soil specimen. By this means it has been variously computed that the average agricultural soil in the United States will be reduced to low fertility in from seventy-five to one hundred and fifty years—a small period of time when compared with the thousand years which the soils of western Europe have been farmed, and more than four thousand years in China, Japan and Corea.

It is not pertinent to the discussion at this point to give the rates of fertilizing which Doctor Hopkins advises by means of chemicals. On normal soils he believes that, of the mineral elements, only phosphorus is deficient. On abnormal soils, such as drained swamp lands and some sandy soils, the potash element too is deficient. This is conceded by all investigators in the science of soil fertility. But Doctor Hopkins believes that even on normal soils, when hay, straw, potatoes and root crops and market vegetables are sold off the farm, potassium must eventually be purchased and returned to the soil. Lime is deficient in some soils, and all investigators agree that in special instances it must be returned to the soil in the form of ground limestone. They disagree,

however, on the function of lime in the process of plant growth.

One more quotation from Doctor Hopkins will conclude the presentation of the generally accepted theory of the plant food requirements of plants and its "availability":

"Probably there has never been a greater waste of time and effort in the name of science than in the endeavor to determine the 'available' plant food in soils. The almost universal assumption has been that the plant food in the soil exists in two distinct conditions, 'available' and 'unavailable' and that the determination of the 'available' plant food would reveal both the crop-producing power of the soil and the fundamental fertilizer requirements for the improvement of the soil for crop production.

"After ascertaining the total stock of plant food in the plowed soil, the next important question is not how much is 'available,' but rather how much can be made available during the crop season. In other words, we must make plant food available by practical methods of liberation, by converting it from insoluble compounds into soluble and usable forms; for plant food must be in solution before the plant can take it from the soil. For the present, space is taken only to emphasize the value of decaying organic manures in the

important matter of making plant food available; and attention is also called to the fact that the decomposition of the organic matter of the soil—including both fresh materials and old humus—is hastened by tillage and by underdrainage, which permit the oxygen of the air to enter the soil more freely, oxygen being a most active agent in nitrification and other decomposition processes of organic matter, as well as in the more common combustion of wood, coal, and so forth."

Do soils wear out?

The hypothesis of Liebig and those who have followed in his path and accepted his theories with the utmost literalness say unequivocally that they do. Neither is it a remote contingency in their eyes; it is immediate. They take the onus for the lack of bounty in the soil from the shoulders of man and shift it to Providence. Providence has been parsimonious with the elements of the bread and meat we would eat. Nature has provided two storehouses from which we may extract food. One is the soil itself. The other is the mines of plant food minerals which we may scatter in the soil, when the land shows signs of exhaustion. They have computed, as we have seen, how long the soil will continue

to feed us, if left to itself. They have not yet taken the pains to compute the extent of the mines of potash, phosphorus and calcium. Why not? We have already begun to mine these concentrated plant-foods in great quantities, in response to their urgings, and encouraged, apparently, at least, by the beneficial results to be obtained in the immediate crop by such a system. It should be just as necessary to know how much chemical plant food will be ultimately available in the form of commercial fertilizers as how much coal, iron or gold we can extract from the earth.

Any way one examines the hypothesis, carried to its logical extension, it is a theory of inevitable doom. Southern Illinois has enough phosphorus to grow ordinary crops for seventy years, we are told. The Leonardstown Loam, they tell us, is already in process of active abandonment. How long, then, before the earth's crust will become a sterile waste, devoid of living things because the means for sustaining life have been consumed?

CHAPTER VII

THE SOIL AS AN IMMUTABLE ASSET

"The soil is the one indestructible, immutable asset of the Nation. It is the one resource that cannot be exhausted; that cannot be used up. It may be impaired by abuse, but not destroyed."

THIS is the pronunciamento of the federal Bureau of Soils of the Department of Agriculture at Washington. It was first published in 1908, and was met with a storm of criticism.

There is no middle ground. The hypothesis put forward by Director Milton Whitney, Doctor Frank K. Cameron, Doctor Oswald Schreiner, Edmund C. Shorey, and other scientists, with the authority of the United States government at their back, states flatly that *soils do not wear out.* On the other hand the whole system of teaching in our agricultural colleges is founded on the theory that

soils *do wear out*. The counsels of the agricultural press, which is an influence that gets closer to the farmer than any other, official or otherwise, likewise teaches that the farmer must feed the soil in proportion as his soil feeds his crops.

It is not surprising, in view of the weight of authority against the new hypothesis, which would rob the old system of the very keystone of its arch, that this new theory should be met with the most violent opposition. Jeremiah, the farmer in the field, has not yet heard of this cheerful theory which takes the burden of unproductive soils from the shoulders of Providence and shifts it to the shoulders of the farmer himself. He has not heard of it for several reasons. In the first place his neighbor's son who returns from college equipped to enter the profession of teaching the science of agriculture is a product of the prevailing school.

In the second place the scientists of the federal Bureau of Soils have as yet made no effort to prepare the hypothesis in popular form. They have published many scientific treatises, giving the data of their experiments and researches in technical form. These publications

are available, it is true, in limited editions, but they are *for sale* at the cost of printing and binding. The American farmer is too accustomed to get his literature for nothing to take kindly to paying for something which, the chances are, he cannot understand in its present form.

Having demolished the keystone of the arch in the orthodox explanation of the fertility of the soil, it became incumbent upon the scientists of the Bureau of Soils to furnish other explanations of fertility or the lack of it in soils. They do not deny that some soils are more fertile than others.

They do not deny that the use of commercial fertilizers, which has grown to be an enormous industry in the last fifty years, is without good results.

They assert that the minerals—potash and phosphorus—are at all times present in the normal soil in inexhaustible quantities, and that they are "available" as plant food at all times, and in sufficient quantities for maximum crops.

They do not take the position that the plant food in commercial fertilizers is not as efficient as the plant food already in the soil in infinite

quantities. They do assert, however, that the function of commercial fertilizers is something infinitely more complex than the theory of Liebig as taught to-day would lead one to suppose; and that of all the profound influences the accepted chemical fertilizers exert on the soil, that of supplying "plant food," as such, is probably among the least important.

The old theory of infertility being due to insufficient minerals in available form has been so thoroughly accepted as a sufficient explanation that the nature of the organic constituents of the soil, and their influence in affecting fertility, were spheres of research that were neglected for a long time. The federal Bureau of Soils is the first body of scientists in the world to devote systematic study to this side of the question, and as the result of their researches they have established the fact that the organic element is quite as important as the mineral element in explaining fertility. The part played by molds, bacteria, enzymes, "the unseen flora and fauna of the soil," and wonderfully complex organic compounds, either tonic or toxic, in their effects on plants, has been the subject of this investigation, and a

number of theories have been put forth, which, no matter whether they stand or fall under the attack of further research, are of prime interest and importance to the farmer of to-day and the farmer of to-morrow. It is in this phase of research that the Bureau of Soils is now expending its energies. The work has not yet reached a point where they are willing to assert definitely just what part these important factors play in soil fertility. With the inveterate caution of true scientists, these men are as yet more given to postulates than to definite conclusions as to the results of their work in this field.

To begin with, early in the course of their work, the Americans succeed in laying low, for all time, the fallacy that a chemical analysis of a soil, as to its mineral constituents, is of value in determining its cropping abilities.

The farmer in the field has not learned this truth yet, but the experiment stations of the world have united in accepting it. Regardless of whether one views the mineral element as something definite and limited as to quantity or not, the statement that any particular soil contains so many pounds of the various elements to the acre 12 inches deep is not worth

the paper it is written on so far as telling what that soil will produce at any given time.

The old school accept this as true because they know that such an examination gives them only the bulk of the minerals present, with no indication of how great a percentage may be "available," as they say. What is "unavailable" to-day may be available to-morrow or next week or next month, according as a variety of causes operate to liberate the "plant food."

The new school reject such an analysis on the ground that the mineral content is never in a stable condition. It is constantly being added to, or subtracted from, by profound forces active at all times. They do not bother themselves with the query whether or not the "plant food" is available, as they believe, if the minerals themselves are present, the plant food is available in fixed proportions at all times. Whether or not the plant can make use of them is another matter, determined by the proper functioning of the plant itself, and the soil itself.

What is of utmost importance, however, is the physical condition of the soil. This affects its immediate cropping qualities. It tells the

farmer if his soil is in proper condition to work at the highest efficiency provided the other influences are working smoothly. Broadly speaking, a soil consisting of fine soil grains is more productive than a soil that is coarse and lumpy, for the simple reason that fine grains retain moisture to the best advantage, and permit water and air to circulate freely.

Therefore we can say without stepping on anybody's toes that *the size of the soil grains which regulate air and water supply is more important than chemical composition.*

All scientists in the problem of soil fertility agree in the beginning as to what constitutes the principal food of plants. The elements enumerated in the last chapter in the quotation from the writings of Doctor Cyril G. Hopkins are the accepted list.

Carbon, oxygen and hydrogen drawn from the air and water are one important branch. All schools believe they exist and are available in infinite quantities.

Nitrogen, according to Sir William Crookes, is becoming so scarce that the world must stop growing wheat in another fifty years. How-

ever, this doleful prediction has been swept aside as untenable by accepted theories. The air we breathe is four-fifths nitrogen, and Hellriegel in 1886 was able to isolate a bacterium from the roots of clover, whose function is to extract nitrogen from the air and make it available for plants. It is estimated that upward of 35,000 tons of nitrogen hangs suspended over every acre, and, were there no other means of putting it in the soil than the bacteria of legumes, there need be no fear that any farm acre, under proper systems of cultivation and rotation, will ever be deficient in this element.

There are other means of extracting nitrogen from the air. There are other flora and fauna of the soil which make it their main task to extract it from the air and manufacture it in the form of nitrates. Mr. A. D. Hall of the Rothamsted station, the most famous experiment station in the world, tells (Chemical News, Vol. 106) how a soil that was permitted to run wild for 23 years was found to have gained 92 pounds of nitrogen per acre each year. As nitrogen as a commercial fertilizer is worth upward of 18 cents a pound, the importance of this fact can be seen. In this

particular case, the nitrogen was added by the *azotobacter* present in the soil, bacteria which feed on the decaying carbohydrates to be found in suitable form in many plants. This discovery suggested a pretty experiment to the investigators of Rothamsted. They used starch and sugar (which contain none of the so-called mineral plant foods) with wonderful results. Starch and sugar are carbohydrates and thus furnished the necessary food in concentrated form for the busy bacteria.

The experiment all but failed, because of a peculiar accident which illustrates the many complex forces that must be taken into account by the soil expert. The first dressing, consisting of a ton of sugar to the acre, gave no results whatever. In fact the crop of barley which succeeded the application was a total failure. It was suggested that possibly the sugar "fertilizer" was applied at a time of year when the tiny micro-organisms were inactive. It had been applied in winter. A second test, with the sugar applied in the warm spring months just previous to seeding, resulted in a greatly increased yield of barley.

It was further found that the decaying roots

of turnips exercised the same effect, as these roots are highly carbonaceous. This explained one of the benefits of plowing under "swedes," a practice almost as old as agriculture itself.

"When neither clover is grown, nor the roots of turnips put back," says Doctor Hall in commenting on his experiments, "the soil is losing nitrogen; when both take place during a rotation, the average removals from the soil become as high as 35 bushels of wheat, 34 bushels of barley and 2 tons of clover hay, yet the soil is gaining in fertility though no extraneous nitrogen is being introduced."

Speaking of the farming of the future in the light of this discovery, Doctor Hall is led to say:

"The only way is to bring the flora and micro-fauna of the soil under control. Partial sterilization effects this; such antiseptics as chloroform, toluene, etc., eliminate certain organisms which check the useful bacteria. Heating to boiling for two hours doubles productivity and is practical in greenhouses.

"The problem of the future is to domesticate the unseen flora and fauna of the soil, the useful races to be encouraged, the noxious races suppressed."

In the light of this discovery, sugar, starch, chloroform, and other chemicals are fertilizers. So is boiling water. How much "plant food" do these substances contain, according to the theory of Liebig? The followers of Liebig value "fertilizers" only in accordance with how much "plant food" they contain. In the strict sense of the term, these materials contain no "plant food." Sugar and starch are made up of carbon, hydrogen and oxygen only. Yet adding them to the soil increases productivity.

Even without the aid of the "domesticated" bacteria and fungus growths, however, the farmer need never run short of the supply of nitrates required for food. If land becomes too valuable to grow clover in rotation, or to turn under carbonaceous green crops to rot and feed the *azotobacter,* man has devised a means of extracting nitrogen from the air mechanically. A current of air is directed against an electric arc, and the nitrogen becomes oxidized. This nitrogen can be gathered by spraying the oxidized air against lime, with which the nitrate enters into combination. This discovery was not due to the needs of the farmer. As we have said, the requirements of

nitrates for war are many times greater than those for peace; and chemists seeking a new source of nitrogen for explosives hit on the electric arc as the means. This invention has already come into use agriculturally in Norway, where only 1.3 per cent. of the land is susceptible to farming, and therefore cannot be spared as a nitrogen factory itself. The government is utilizing many thousands of electrical horse power, generated by mountain streams, for this purpose. Here is a form of "commercial fertilizer," then, that is not futile. Yet we have just seen that the average farmer can attain the same result in his fields automatically by proper rotations, or adding decaying organic compounds *which contain no nitrogen in themselves,* but are merely the food of microscropic creatures that manufacture nitrates.

It will be readily comprehended, then, that the element nitrogen, upon which Liebig laid especial stress, and which Sir William Crookes thought to be the most elusive and scarce of all, is always present in sufficient quantities in all farm soils, providing only that the farming is carried on according to accepted traditions. Science has nothing to do with it.

Science merely explains a condition in this instance.

The two schools separate here.

The established school teaches that potash, phosphorus and calcium are not only limited in ultimate quantity, but enter soluble combinations so slowly that they must be added in soluble form to maintain fertility.

The new school says that these three elements are not only present in inexhaustible quantities, but are at all times soluble, no matter in what form they may exist.

The parting of the ways comes with the meaning of the word "available." Both agree that plant food must be in solution to be made use of by plants.

What is soluble?

Everything is soluble, in everything else, say the scientists of this day. It is merely a matter of degree.

A statement that gold is soluble in air would probably be laughed to scorn by many. Yet that gold is soluble in ordinary air is a fact recognized by all metallurgists and to such an extent that only recently it was seriously suggested that ordinary weighing machines such as are used in the federal assay offices

are sensitive enough to weigh the gold lost in this way over a course of months in any considerable bulk of metal.

Gold is soluble in lead, and lead is soluble in gold. This fact can be demonstrated in any laboratory. Place two bars, one of gold and the other of lead, in contact with each other, and raise the temperature to 300 or 400 degrees F. In the course of a few hours it will be found that minute particles of gold and lead have penetrated the two bars and respond readily to the usual reagents.

Ordinary glass is more soluble in water than is generally supposed. Water standing in a tumbler gradually dissolves silicates, but in minute quantities. However, if one take the same tumbler and grind it up into flour-like particles, so as to increase the surface presented to the action of the water millions on millions of times, it will be found that the glass enters readily into solution. One can take such a solution after a few hours and evaporate it to dryness and weigh the residue of silicates. It amounts to *three per cent.,* nearly as much as ordinary bichloride of mercury; yet if any one would venture the assertion that glass is as soluble as mercury

he would not be believed by the unscientific audience. The fact is that glass enters so readily into solution that this item must be taken into consideration in all delicate laboratory analyses. Otherwise the presence of silicates in the test solution could not be explained.

One more instance—it is a well known fact that soft metals, such as pewter, lead, etc., dissolve brass when the brass is applied as a plating. Unless the object is first subjected to a plating of nickel, the brass is soon drunk up by the greedy soft metal. Plated goods "wear." It is always a problem how much of the plating is actually worn off, and how much is absorbed by the metal used as a base.

What application have these scientific truths to the fortunes of Jeremiah, the farmer of to-morrow?

They strike at the very root of the theory which actuates the lever of his fortunes.

Thus he is taught that potash and phosphorus are not soluble in the original form in which they exist in the soil. They must be subjected to the processes of weathering, be broken down and forced to combine with

radical bases—turned into "soluble salts" before they can be utilized by plants.

What if it were true that the weathering process is not necessary? What if it were true that ordinary potash and phosphorus are capable of entering into solution in sufficient strength to feed plants as fast as plants could make use of this mineral "plant food"?

Such is actually the fact if one may have confidence in the results obtained in experiments by the Bureau of Soils chemists.

Furthermore, these experiments seem to establish the fact that the absorptive powers of the ordinary soil are such that no matter how much soluble salts in the form of commercial fertilizers is added the strength of the solution present in the soil is always constant. It is beyond the power of the farmer to change the balance of the plant food solution which Nature herself establishes and maintains inexorably.

Here is a simple experiment illustrating the point. Take a sample of any farm soil, and extract its soluble salts by agitating the soil in distilled water. Heat the water if you choose, let it remain in contact with the soil grains an hour, 10 hours or 100 hours. Then

analyze the supernatant liquid. Set down in black and white how much potash and phosphorus the water contains.

Next, take another sample of the same soil, and "dress" it with commercial fertilizers in their most soluble form. Mix them thoroughly with the soil, and let the mixture stand for some time to insure the soil moisture acting on the chemicals added.

Then treat this "fertilized" soil in exactly the same way you treated the first sample. Extract all the soluble "plant food" possible with distilled water for the same number of hours. Then analyze that water. The result is surprising.

The two analyses will be practically the same. There is no more potash or phosphorus in the second solution than the first, in spite of the fact that you have "fed" this soil with these elements in their most soluble form. You cannot recover these salts by solution. The soil has seized upon them and retained them as its own, and will liberate them only at a definite rate.

It may be asked in this connection—what element of fertility does the farmer add to his soil when he applies mineral salts? Has he

increased the "available" plant food of his acres? The foregoing experiment on his own soil would prove that the addition of salts of potash and phosphorus has not effected any additional concentration in the soil solution; and it is an established fact that a plant cannot extract food from the soil unless that food is in solution.

This experiment suggested a new world of experiment to the investigators. The problem of why soluble salts cannot be extracted from the soil by water is something aside from the discussion at this point. The mere fact that they cannot is of first importance, coupled of course with the fact that the concentration of the soil solution remains practically constant, no matter how much soluble salt may be in the soil.

It is objected in this connection that the test is not fair, because the first sample of soil surely contained "soluble" or "available" minerals innately, and it was these that entered into solution to saturation.

In answer to this objection, the experiment can be conducted not with soil itself, but with rock-forming minerals. They can be obtained from any museum collection. The rock-form-

ing minerals that make up our soils are practically the same the world over, so the experiment holds good for broad conditions. Take these ordinary rocks and grind them in a mortar until they are as fine as the soil particles themselves. How fine this should be can be determined by the number of particles required to form a linear inch. In our clay soils, the particles number 5,000 and over; in silt, 500 to 5,000; very fine sand, 250 to 500; fine sand, 100 to 250.

Thus a cubic inch of clay would contain 125,000,000,000 particles. This type of soil is an ordinary one. By a calculation it is simple enough to determine how much greater surface it would present to the soluble action of water than if the clay were a solid cube of one inch dimensions. Apply the parallel of the solubility of glass here.

Such a test actually was made by Frank K. Cameron and James M. Bell (The Mineral Constituents of the Soil Solution, Bulletin 30, Bureau of Soils), and prolonged over a course of months. It was conducted by means of an ingenious electrical contrivance which insured a continuous flow of water over the rock particles.

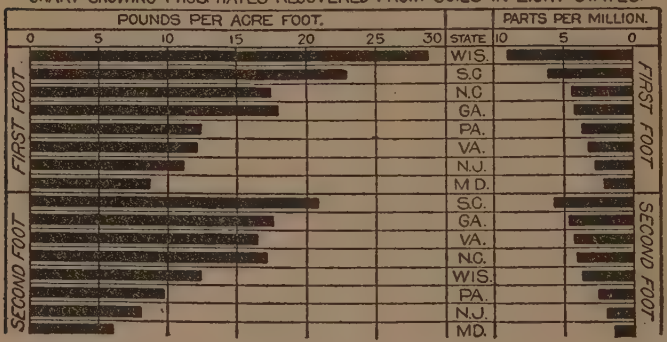
The density of the solution thus obtained practically remained constant after the first leaching, and was almost identical in its content of phosphoric acid and potash with a solution obtained by leaching the soil itself. Another method even more exact is by measuring the electrical resistance of distilled water as it leaches through rock particles or a sample of soil. Continued experiments by this method, too, show that the percentage of "plant food" entering solution remains practically constant.

The theory that all soils contain "plant food" in inexhaustible quantities, and that these minerals are at all times available by solution or hydrolysis, was not suggested originally by the scientists of the Bureau of Soils. It was first put forth as a possibility by Samuel W. Johnson. ("How Crops Feed," 1884.) In a work treating with the general phases of soil fertility he details a number of experiments showing that successive and separate leachings of a soil sample gave practically uniform results.

Professor Milton Whitney shows (Soils of the United States, Bulletin 55, Bureau of Soils) that, in the average soil solution obtained by contact with water and the soil

grains, there are 25 parts per million of potash and 10 parts of phosphoric acid. The results he obtained did not vary, even though one sample was found to contain 30,000 parts of potash reserve, and another 120,000; and one soil contained 5,000 parts phosphoric acid re-

CHART SHOWING PHOSPHATES RECOVERED FROM SOILS IN EIGHT STATES.



From Bulletin 26, Bureau of Soils, Prof. F. H. King.

serve and the second 20,000. These results are again almost identical with experiments conducted under actual field conditions in eight states by the late Professor F. H. King of Wisconsin. In a single leaching by distilled water he recovered from 3 to 9 parts per million of phosphates. (Investigations in Soil Management, Bulletin 26, Bureau of Soils, p. 51.)

These experiments established one conclusion, i. e., that the rate at which plant food enters solution in the soil—is available, in other words—is fixed within narrow limits and that it always tends toward an equilibrium as the plant extracts its "food." Thus continuous leachings do not rob the soil of its capacity for furnishing fresh solutions of fixed densities and the addition of highly soluble fertilizer salts, such as muriate of potash, or ammonium phosphate, does not seem to affect the density of the solution. The soil merely absorbs the excess, holds it in reserve.

A solution of 10 parts per 1,000,000 is almost infinitesimal, yet it is sufficient to support plant growth, as has been shown by hundreds of experiments. Average soil solutions covering thousands of experiments give about 27.3 parts of potash and 8.5 parts of phosphoric acid. Do such low concentrations sustain and promote plant life?

Undoubtedly they can, and actually do.

Many years ago it was found that mature crops of good yield could be grown in well water containing only 18 parts of potash and 2 parts of phosphoric acid. And very satisfactory growth of wheat was obtained from

Potomac River water, which was found to contain only 7 parts of potash. Johnson tells of an experiment with well water which contained but 1½ parts per ten million of phosphoric acid, and notes that this solution gave twice as much grain as a solution from field soil.

In actual field tests in the growing of crops there is no room for wonder that plants thrive when their nutrients are supplied at so slow a rate. The roots are constantly extracting the soluble minerals from the solution and re-solution is going on continually. This has suggested the query to many investigators of how dilute a solution may be before plants lose the power of feeding from it. There are certain plants which extract iodine from sea water and store in it their tissues in sufficient quantities to make its extraction profitable in a commercial way. Starch added to a solution is a delicate test for the presence of iodine, so delicate indeed as to give positive results with one part in 300,000. But the amount of iodine in sea water is so small that it does not respond to the starch test. In an experiment, sea water was evaporated to one one-hundredth of its former bulk—that is, the solution was concentrated one hundred times. Still the chemist

was unable to get a reaction of iodine in the concentrated solution. This seems to prove beyond doubt that plants actually do extract iodine from sea water containing less than one part iodine in 30,000,000. In much the same way the gigantic submarine plant, kelp, extracts potash from sea water in enormous quantities. It has recently been seriously proposed that kelp will become an important source of our future potash supply.

In spite of the fact, however, that plants can, and actually do, make use of their food in these dilute solutions, a mere scientific demonstration is of no value to Jeremiah, the Farmer of To-morrow—unless it can be proved at the same time that such dilute solutions are capable of producing crops in paying quantities.

If the plant in either the test solution or in actual field conditions merely sustains growth the experiment is useless. If on the other hand it can be shown that the normal rate of solution of these supposedly insoluble minerals is capable of producing bountiful crops then the secret is of tremendous economic importance.

The promulgators of the new hypothesis are

able to go even farther than this demand. *They are able to prove that plants actually attain their best growth at these figures.*

Potash at 25 parts per million and phosphoric acid at 10 parts is not only a sufficient, but an optimum concentration. The tables (Bulletin 70, Bureau of Soils) on page 237 illustrate the point.

In connection with these tables it should be explained that the solutions used contained soluble salts of the three elements in distilled water—nitrogen, potash and phosphoric acid. Where only two of these salts were used it was found in many cases that the plants attained as great a growth as where the optimum quantity of the missing element was added. This would seem to nullify the results, except for one interesting fact developed—that plants grown without any one of the three elements, but with a sufficiency of the other two, developed peculiar pathological qualities that would not be tolerated in actual farming conditions.

From the table showing results with potash it would appear that the best results in growing seedlings was attained when the nutrient solution contained between 24 and 32 parts of potash to the million.

SHOWING THE RESULTS OBTAINED FOR POTASH (K_2O) IN THE CULTURES CONTAINING DIFFERENT AMOUNTS (Page 91):

Potash content K_2O *parts per million*	*Green weight of plant grams*
80	1.106
72	1.922
64	2.661
56	2.890
48	3.222
40	3.600
32	3.929
24	3.877
16	3.538
8	3.172

The table shows a decided falling off in the productiveness of this solution when a concentration of 56 parts is reached, and in the culture containing 80 parts the plant produced less than one-third the green weight it was able to produce with from 24 to 48 parts.

The table giving the results of phosphoric acid experiments is equally instructive. Thus:

SHOWING THE RESULTS OBTAINED FOR PHOSPHORIC ACID (P_2O_5) IN THE SOLUTIONS CONTAINING DIFFERENT AMOUNTS (Page 87):

Phosphorus as P_2O_5 *parts per million*	*Green weight of plant grams*
80	0.648
72	1.226
64	1.983
56	2.580
48	3.045
40	3.340
32	3.295
24	3.308
16	3.558
8	3.640

Here we find the concentration of the phosphate element of plant food producing the best growth when it is only 8 parts per million. At 56 parts the slowly declining line takes a sharp drop, until at 80 the "crop" produced in these solutions was less than one-fifth that of 8, *although the available plant food was present in ten times the quantity.*

The results of these experiments seem to establish one point beyond doubt—that Nature herself has provided a definite ratio at which she liberates the mineral food of plants, and that this ratio is fixed. Furthermore, if the above experiments are worth anything they prove that the plant has adapted itself to this fixed ratio, in much the same way as man has adapted himself to three meals a day, and that any attempt on the part of the experimenter to vary this ratio, even within very narrow limits, is disastrous to the plant, results in "crop failure."

These facts seem to verify themselves in the laboratory. Do the same conditions actually prevail in farming? Does the soil present the same peculiarities as a laboratory test solution?

Naturally, in an hypothesis so much at

variance with the established teachings, the scientists who "stand pat" on the Liebig theory say they do not.

This brings us back to the question of what becomes of the soluble salts in the commercial fertilizers which we add to the soil in order, so we are told, to increase the amount of "available" plant food.

The experiment of adding these chemicals to the soil and trying to extract them again by distilled water seems to prove that we have not affected the ratio of liberation in the least. What has become of this plant food? In an actual test, 4,000 parts of very soluble potash was mixed with 1,000,000 parts of soil. Yet distilled water extracted only 25 parts at a time. It seemed impossible to raise the concentration of this solution no matter how long the water was left in contact with the soil. So with phosphoric acid.

The soil grains absorbed the salt.

The absorptive power of the soil is a phenomenon that has been observed for many years. As far back as 1859 (American Journal of Science and Arts), Johnson put it thus:

"The soil, speaking in the widest sense, is then not only the ultimate exhaustless source of mineral (fixed) food of vegetation, but is the storehouse and conservatory of this food, protecting its resources from waste and too rapid use."

In 1879 the same author (How Crops Feed) said:

"Those bodies which are most rare and precious to the growing plant are by the soil converted into and retained in a condition not of absolute, but of relative solubility, and are kept available to the plants by the continued circulation in the soil of the more abundant saline matters."

If red ink is passed through soil it is no longer red ink. It is clear water, so avid are the soil grains for certain elements. If nitrate of silver is passed through finely divided charcoal the solution that leaches out consists of nitric acid, and with a glass one can discover fine spangles of silver in the charcoal. The absorptive power of sand was used in Bacon's day as a means of extracting salt from sea water. The commercial use of this property is common in our everyday life. We refer

to such absorptive substances as filters. This power is not equally potent for all substances. The soil exercises a selective property, as, for instance, it has a greater avidity for potash than for chlorine.

The property is founded on the fact that the surface of solids, such as soil grains, has a tremendous attraction for solutions. Supposing a metal ball to be composed of an infinite number of molecules, each exerting an attraction for each other, the forces acting on the molecules in the center of the ball are equal on all sides, therefore the molecule can move about freely. Those molecules on the surface, however, are being drawn only toward the center of the ball, as the attraction of the surrounding air is much less than the interior of the ball. We are not accustomed to regard a film of water on a plate of glass as possessing unusual dynamic qualities, yet it is being attracted to the glass by a great pressure.

Thus, the film of soil moisture surrounding a soil grain is held as a tight skin around the grain under a pressure that is variously estimated at between 6,000 and 25,000 atmospheres. If it were 10,000 atmospheres, the pressure exerted would be (Bulletin 55,

Bureau of Soils, p. 11) at the rate of 150,000 pounds per square inch, or approximately fifteen times the muzzle pressure of a 12-inch gun. It is in this film surrounding the soil grains (which, we have seen, actually exist at less than 1-125 billionths of an inch in diameter) that the plant food solutions are held in great concentration due to pressure. It is this property of soils that holds the excess "plant food" and liberates it to the circulating soil waters at a definite rate. Thus the soil conserves its own resources by a method almost beyond the conception of man.

CHAPTER VIII

THE EVIDENCE OF HISTORY AND RESEARCH

Granting, for the purpose of argument, that the mineral plant food in the soil is available at all times to plants in optimum quantities, and that, generally speaking, the rate of solution cannot be hastened or retarded, we are still face to face with the proposition that there is an end to the supply of these minerals.

Doctor Hopkins, as we have seen, states that the earth's crust contains about 49,200 pounds of potassium and 2,200 pounds of phosphorus to 2,000,000 pounds.

It is estimated that an acre one foot deep of soil in New York State contains 35,000 pounds of potassium and 2,500 pounds of phosphorus, and 20,000 pounds of lime.

Does not this constitute a definite bank account of mineral fertility, paying interest to the farmer in the form of crops out of its

capital? It is so regarded by those who urge the use of mineral fertilizers only as "plant food." We must believe this if we believe that our soils are wearing out, as we are being told on every hand. If our soils contain only sufficient quantities of any of these ingredients to feed us one hundred or two hundred years, surely it is a matter of national concern.

Here again the promulgators of the new hypothesis take the opposite ground. They believe that the normal agricultural soil will never be deficient in minerals. They have a different conception of the nature of the soil from the old school.

Briefly they tell us "We are not farming the same soil as our fathers farmed."

It is changing continually.

The study of the broad science of geology did not make much progress until the scientists recognized the fact that geological changes are as much due to quiet forces that are at all times at work as to great cataclysms of Nature. The blowing of the winds, erosion, the profound movement of ground waters, and a hundred other subtle agencies are at all times working their miracles. They are too subtle, except in rare instances, to be measured in a

year or a generation, but over thousands or hundreds of thousands of years they accomplish enormous results.

These same agencies are operating at all times in the soil. The most important to the the farmer of to-day is the movement of ground waters.

Water exists in the soil in four different forms: the water of hydration, hygroscopic water, capillary water, and gravitational water. The water of hydration is that which combines chemically with the minerals as hydrates and is not, as a rule, available for plants.

Hygroscopic water is that which adheres to the soil grains as films and contains the mineral nutrients of plants under high pressure.

Capillary water is that which moves freely between the soil grains by capillary attraction. This is the principal source of food for plants, the "carrier" as it were of the food.

Gravitational water is that which escapes to the depths, as excess beyond the ability of the soil to retain it, and in the best farming practice is carried off by means of drains.

The point to remember in this connection is that the water which goes down—the gravitational water following a rain—is not of so

much immediate importance to the plant as the water that comes up—the capillary water. Gravitational water passes quickly through a well-drained friable soil, seeking the water level below. This may be a matter of inches or feet, according to the nature of the particular soil. After a heavy rainstorm the drains are filled not by water from above, but by the rising of the so-called water-table from below.

Drain waters for this reason contain, as a rule, much less "plant food" than do capillary waters, having remained in contact with the soil for only a brief period. Yet, if one adheres to the theory that the mineral resources of the soils are so limited in quantity as to be exhaustible in the history of man on earth, he must also subscribe to the belief that the loss from leaching through drainage is in time enormous. We have already quoted an estimate as to the amount of fertility lost in this way—potassium, 51 pounds; magnesium, 16 pounds; calcium, 5 pounds, and phosphorus, 42 pounds per acre in four years' time. According to many estimates, these quantities are sufficient to grow a crop; and, thus, every fourth year the equivalent of five crops have

been taken from the soil by the combination of cropping and drainage.

Extend this calculation not over four years or forty years, but over four hundred or four thousand years and one's amazement is that we find any minerals left in the soil at all. Leaching has been going on for ages, in virgin prairies as well as on cultivated land. So even gravitational water, with its low content of plant food, becomes an enormous item in time, if we subscribe to the bookkeeping theory.

Gravitational water becomes capillary water when evaporation begins at the surface. It begins an upward journey. It does not travel now by the broad highways that hurried it downward when the upper soil was too saturated to hold it.

Instead, it moves from grain to grain of soil, picking up its ration of solutes from the film water surrounding each grain as it passes. Its mode of passage can best be illustrated by water flowing across a screen door. This water, as we frequently have opportunity of observing, moves in squares, blocking off the meshes of the screen. So the capillary water deep in the earth moves among the interstices

of the soil grains, picking up its modicum of "food" in its flight. So it is the water that comes up from the depths and not the water that goes down from the surface that feeds the plant.

As this water approaches the surface, evaporation becomes more and more rapid. Each molecule, when its time comes, disengages itself from the mineral "food" it has picked up in passage—(its modicum of 25 parts per million of potash and 10 parts of phosphorus, etc.)—and escapes into the air as vapor, leaving behind its parcel of "food" in the upper strata of soil.

Who will say that an examination of the mineral content of the upper twelve inches of soil gives any true indication of that acre's future store of mineral fertility?

The content is being constantly augmented by the evaporating capillary water, and, on the other hand, it is being constantly "swept" by the gravitational water, which, in its flight to the lower level, picks up a part, but not all, of the "parcel of food" that had previously been carried to the top. Thus we see that the "number of pounds of potash and phosphoric acid"—by which some would measure the life

of a soil—is not a constant quantity at all, but, on the other hand, is changing continually even during infinite sections of a single second.

This is one method by which the movement of ground water changes our soils so that "we are not farming the same soils as our fathers." A simple experiment demonstrates the truth of this statement. A column of soil contained in a bottomless tube several feet high is made to rest in a basin containing common salt in solution. Then the air is agitated gently at the surface of the column, so as to induce evaporation—simulating the winds that blow, in fact. In only a short time an analysis of the top layer of soil reveals the fact that molecules of salt—common table salt—have been transported through several feet of soil and abandoned at the surface by the elusive, vaporizing molecule of capillary moisture.

The movement of soil waters is profound. No one has ever "fetched bottom" in gravitational water in the soil. Whether the resources of the upper soil are being fed by water columns measured in feet or in miles no one can say. It is probable, however, that the movement is continuous from a great depth.

These facts emphasize the necessity of keep-

ing the soil in good tilth, as the saying goes, in other words, maintaining the most favorable condition for the movement both of gravitational and capillary water. These two factors are adjusted to a great extent by accepted methods of cultivation and drainage, while, on the other hand, the action of the waters of hydration and hygroscopic water are largely beyond the control of man. The movement of capillary water is influenced by cultivation, which conserves moisture, by establishing a dry mulch as a cover to the soil to prevent the escape of the water burdened with its food particles and holds it for use by the roots of plants.

How much of a factor the blowing of soils may be in altering their composition and texture is difficult to determine. It is safe to assume that it is much more important in all climates than is usually imagined. In the Great Plains area, under peculiar conditions, the blowing of soils is such an important factor that efforts are now being made to acclimatize trees to form wind-breaks. On the Maryland peninsula, where many of the roads are constructed of crushed limestone, farms adjacent to highways never get "sour"—which

is another way of saying that the lime present in the soil is always sufficient to overcome and neutralize the acid effects due to decaying vegetation. Here the farmers have their soils "limed" continuously by the dust from the highways.

It seems evident that if the physical texture of a given soil is favorable to the movement of ground waters, that soil will be forever "fed" from the inexhaustible storehouse that Nature has provided. Limited, in a broad sense, yes; but attempts to sound the day of doom seem as futile as trying to empty the boundless ocean with a tin cup.

"The soil is the one indestructible immutable asset of the Nation. It is the one resource that cannot be exhausted; that cannot be used up. It may be impaired by abuse, but not destroyed."

The logical extension of the theory of "immutable assets" is that all soils are equally fertile. This is true, in a general way, on normal soils, soils of a texture which is accepted as necessary in farming practice. It is easy enough to note exceptions without end. These exceptions only go to prove the truth of the theory, as the trite saying runs.

However, the statement that all soils are equally fertile must be qualified by the additional statement—*only in so far as the presence of minerals affects fertility.*

The opponents of the new hypothesis have, in many instances, seized upon the general statement without regard to its qualifying clause and held it up to ridicule. The champions of the new hypothesis do not deny that soils vary in fertility. But they assume that the factor of mineral plant food is practically fixed and can be ignored in exploring the problem of why some soils are fertile and others are not. They occupy the rôle of physicians diagnosing the ailments of sick plants. If the plants have proper food they should not starve. Yet some plants do starve. It is found they have the proper food, therefore the physicians can ignore the food supply as a factor. They must look for something beyond that to explain the ailment. That is exactly what they are doing in explaining the ailments of plants and soils, as we shall see in the next chapter.

The "exhaustion" of the soil has been a subject of vital concern since historic times.

Two thousand years ago the Romans believed their soils so near depletion that they adopted a system of alternate fallow and cropping. The acres of the Campania district were the wonder of all students of those times because of their ability to produce crops every season without fallow. Fallow is considered a necessary practice in European Russia to-day. The Black Earth Regions of Russia, producing as much wheat as the United States under a most primitive form of agriculture, are cropped only two out of every three years. That is, one-third of the land lies idle every year. It is the belief among the peasants, handed down for hundreds of years, that fallow is necessary to retain the "strength" of the land.

Single-cropping, the evil of an extensive system of farming, such as has been practiced in the United States for the last fifty years, was early recognized as one of the quickest ways of "taking the heart out of the land." Adam Dickson (The Husbandry of the Ancients, Edinburgh, 1788) quotes liberally from Pliny, Virgil, Cato and others, to show that rotation of crops had, even in those times, come to be recognized as a necessity if they

wished the soils to continue to feed the nation. Pliny also recognized the necessity of adapting the crop to the soil, and in this connection he mentions the benefits to the soil to be had from the growth of legumes, "which are pulled up and not cut in reaping; hence they are called *legums* because thus gathered."

Modern Europe early began establishing experiment stations in an effort to determine the exact nature of soil fertility; although it was not until the time of Liebig, about 1840, that active direction was given to these experiments. The United States and other younger nations, recognizing soil fertility as a national asset, and the determination of its nature as a national function, developed experiment stations in great numbers. At the present time each State in the Union has such a station supported by federal subsidy under the Hatch Act, and, in addition, stations supported by state subsidy alone, and still others conducted in connection with agricultural colleges. Thus, there is no dearth of data for one who seeks to study the problem of soil fertility in its numerous branches.

The most classic experiments recorded in the literature of agriculture are those of the

Rothamsted Station in England. The Rothamsted Station was established by Sir John Lawes in 1843, and on his death, in 1901, endowed in perpetuity by him.

Associated with him for more than fifty years was Sir Henry Gilbert, a pupil of the great Liebig himself. It is a noteworthy fact that, although the endowment of Rothamsted is made up from a fortune accumulated in the chemical fertilizer industry, Sir John Lawes never permitted his business interests to sway him in the least in his classic undertaking. In fact, at the time of his death he admitted that the most puzzling problem to be solved was the fact that a field of wheat in rotation, never manured since 1848, produced more grain than another field continuously cropped and continuously fertilized for each crop with a "complete fertilizer."

The Bureau of Soils of the Department of Agriculture does not conduct field experiments. All its data is drawn from the experiments of the state stations and the stations of the Old World. That these American scientists should interpret these orthodox experiments in the light of a revolutionary theory—as sustaining their own theory, in

fact—has been the cause of some bitter recriminations.

In attacking the hypothesis of "immutable assets," the first point considered vulnerable —and dangerous to teach—is the statement that potash and phosphorus are always available in sufficient ratio to feed plants.

Professor Edward J. Russell (Science Progress, Vol. VI), of the Rothamsted Station, examines the theory of the Bureau of Soils in detail, and rejects the assertion of free solubility of the soil minerals as unfounded. He accepts the German theory that soil grains are rendered insoluble by a coating of silicates, which acts in the same way as a hollow glass ball filled with common salt. The glass would prevent the water from coming in contact with the salt and therefore withholds it from solution.

Doctor Cameron and James M. Bell, in their experiments as to the solubility of minerals (Bulletin 30, Bureau of Soils), admit that they reached a point in some of their experiments where further potash could not be removed from soils by leaching without regrinding the soil grains, and state that "this gradual cessation of the yield of potash has

been attributed to the formation of colloidal aluminum silicate on the surface of the mineral particles."

Referring to this possibility, the authors say (page 23, Bulletin 30):

"Silica is a normal product of the decomposition of the minerals and has accumulated in relatively large proportions in the soil. It may be present as quartz, amygdaloidal silica, or perhaps as other forms. But undoubtedly there is a distinct tendency through solution and redisposition for it to be gradually changed from other forms into quartz. Under arid conditions, as is well known, it is common to find the quartz crystals and crystal fragments with sharp clean edges, while they are usually more or less rounded in soils from humid areas. But it is astonishing to find how often even in humid areas the quartz does show clean sharp edges and smooth surfaces, with well-marked terminal planes, apparently due to redeposition from solutions. These facts are important because they tend to negative sometimes expressed opinions, that the silica as it is formed from the minerals either as a colloid or in some other form, coats the minerals and prevents further solvent action on them. Evidence is wanting for the existence of such silica coatings on the minerals of the soil."

They admit that such coating might take place to some extent, but they contend that since silica itself is soluble it could only act as retarding the solution.

The Rothamsted workers accept as established the theory of the Bureau of Soils that the physical texture of soils is much more important in determining the immediate productivity than chemical analysis. Their principal quarrel with the Bureau of Soils has to do with the theories advanced by the Americans as to the part the organic constituents of the soil play in soil fertility. We will examine their objections in connection with a statement of what these theories consist of in the next chapter. It is sufficient to say here that, in the words of Doctor Russell, "they do not accept the American hypothesis, but must admit they have none to offer in its place."

The American opponents of the "American" theory rest their case on their own interpretation of the results obtained in experiments dating, in some instances, over periods of twenty-five years.

This historical data is far too voluminous for the farmer in the field to reduce to broad

principles; yet the results are available to him in condensed form in the annual publications of the various state experiment stations, giving the analyses of chemical fertilizers bought in open market. These fertilizers are usually designated as being especially fitted for wheat, corn, potatoes or other crops, and are supposed to represent the last word in scientific knowledge as to the needs of particular crops. Thus we have systematized formulas indicated for the various crops, founded not on the experiments of the manufacturers themselves, but on the work of the official experiment stations of the many states supported by public funds.

Each manufacturer is bound, under the law, to designate plainly the number of pounds per hundred of the three "plant foods" his mixture contains, nitrogen, potash and phosphoric acid; and if, on analysis of samples bought in open market, his product is found to fall below the specified standard, the manufacturer is subject to prosecution and fine and imprisonment. So well established is the Liebig theory on our statute books, in fact, that the "pure food" law as applied to the food of plants is as definite as that applied to the

food and drugs intended for human consumption.

There is, therefore, no reason for wonder that the average farmer interprets the use of chemicals only in the light of so much plant food added to his soil, and calculates their value accordingly. That is exactly what the state experiment station experts have been trained to do, and, with the weight of the dominant theory impressing them at all times, it is small wonder that they have come, in time, to measure values only through the plant-food factor. Jeremiah, the farmer in the field, reads that the use of $1,000 worth of potash salts, applied to a given field, increased the yield by $10,000 in value. He is not apt to go beyond the implied conclusion that the field must have been lacking in available potash to attain such striking results. He does not inquire into the peculiar climatic conditions affecting the particular crop, the nature of the soil as to its physical characteristics and organic content, or the methods of cultivation or the quality of seed used.

Nevertheless, there is a growing army of experts who are beginning to question more and more the value of the volume of data

dealing with the use of chemicals. The mere fact that a chemical was used in the process of farming a field that proved especially fertile does not necessarily mean that the added productivity was due solely to the use of that chemical. Liebig himself recognized the insufficiency of his theory of mineral requirements. He comments frequently in his writings on the fact that crops do not respond in proportion to the plant food fed to them; in fact, he notes, in many instances, that soils fall off in productivity even when fed freely when subjected to the same crop year after year.

What are these experiments worth then to the farmer?

They are worth nothing, unless he is capable of interpreting them with full knowledge of conditions. Unfortunately, much of the early data is valueless because of the inclination of the experimenters to consider all other conditions as fixed and only the mineral plant-food requirement of soils as varying.

Even when climatic and cultural conditions are identical, the widest range of yields is experienced. The average farmer has no conception of the different types of soils, both physical and chemical, which are to be found

in a single field. Many of the variants are too subtle to be calculated, yet they make for the widest divergence in results.

As an illustration of this point, let us take the data of experiments in wheat fertilizers, 3,227 in number, conducted by state experiment stations, and tabulated by the Bureau of Soils at Washington. It is to be presumed in this connection that the soils used in the experiments, even though they are scattered over the length and breadth of the country, are at least ordinarily suitable for wheat culture, otherwise the work would be useless.

The usual method of experimenting is to divide a field into parallel plots as nearly uniform as possible, both as to fertility and as to size. "Test" or "check" plats are always maintained in connection with an experiment to compare the results with and without fertilizers.

Yet in these official experiments the productivity of the check plats is found to vary in yield from *less than one* bushel to *more than fifty* bushels to the acre. That is, without the use of fertilizers of any kind.

With oats the yield of the check plats varied from less than ten to more than eighty bushels

to the acre. And so with corn, potatoes, all crops. These experiments cover widely scattered fields, it is true, and varying climatic conditions, but in the same acre the most remarkable variations in fertility may be found under identical treatment and climatic conditions. An acre of wheat looks fairly uniform to the naked eye. Yet, if the farmer divides it into twenty-five foot strips and harvests each strip separately he may, probably will, find that the yield of some plats is several times that of others. In one corner he will find more straw, in another more grain, and in a third, barren stalks.

If, now, instead of subjecting the whole acre to uniform treatment, he used part as check plats and divided the remainder among different systems of fertilizing, would he be justified in accounting for the difference in yields by the systems of fertilizing he used? Would he be justified in saying that a dressing of nitrate of soda was the sole cause of a yield of ten per cent. above the average of the other plats? He would not, unless he were in a position to say that all other factors were uniform. And he cannot say that. He does not know, and at this period in the advance

of the science of agriculture there is no method of determining.

When it comes to a question of climatic conditions, the divergence becomes very marked. The yield of corn in the State of Nebraska for the ten years, 1867-1876, varied from 10 bushels an acre in one year to 40 bushels an acre in another year. The soil was new, fairly uniform, and subjected to the same treatment in one year as another. Yet here were thousands of farmers who produced four times as much corn with the same tools in one year as they did in another. The effect of climate on production is so great, in fact, that experiments of a single year are to be dismissed as of little value. That is why scientists turn to Rothamsted for data, because there we find fields that have been under observation for over 65 years. But, in spite of this fact, the experts in charge of the Rothamsted fields are no more able to forecast the behavior of a given field to-day than they were 65 years ago. They know, in a general way, that the use of chemicals has increased yields in a majority of instances; but under certain conditions of sunshine and rain the field that has been most bountifully "fed" may produce

less than a field that has been systematically "starved."

Even in the matter of the chemical analysis of the soil experts seldom agree. There are many methods of determining the mineral content of soil, all stamped with the approval of official and duly qualified chemists. Mix a sample of soil well, so as to insure its being uniform, and ask five men, qualified for the task, for an analysis. Their results will vary in some instances hundreds of pounds of each ingredient to an acre-foot.

The opposing sides of the theory of "immutable assets" both point to the famous Agdell Field at Rothamsted as furnishing evidence to confute each other. Thus statistics are subject to the most diverse interpretation. This field contains one plat where wheat has been grown every fourth year in rotation for more than fifty years. It contains another plat where wheat has been grown every year. In the first instance no fertilizer was applied. In the second the land was dressed with a "complete fertilizer" every year.

What has been the result? On the unfertilized plat the yield of grain has been 1,490

pounds. On the fertilized plat the yield was 1,298 pounds.

Does this establish the fact that the soil itself contained sufficient fertility and that rotation of crops without chemicals gave larger returns than extensive fertilization?

One party to the controversy says that the experiment does not establish this as a conclusion. They say "Let us see what happened when this land was subjected to other crops, such as turnips or barley."

We find that this piece of land in rotation did not produce enough turnips to pay for the seed. Also the barley was low in yield. Thus, in spite of the fact that this plot was sufficiently rich to grow 28½ bushels of wheat every four years, it was not able to grow turnips or barley profitably.

This objection is immediately answered by quoting from Sir John Lawes himself. He discovered, after the experiment had been under way several years, that the physical texture of the soil was not suited to produce either turnips or barley, no matter how rich it might prove to be in minerals. The soil was too heavy to grow either of these crops profitably.

Thus, one unconsidered factor nullifies the value of this classic experiment.

China, as we have said, presents a history of four thousand years for the study of the agricultural scientist. So closely does this nation press the limit of her acres that floods or prolonged droughts spread famine in their wake. The soils of China are capable of sustaining her population, more than fifteen times as dense as our own, when the weather factor does not swing too violently to one side or the other.

The evidence seems undeniable that her soils are more productive to-day than they were four thousand years ago. One-half an acre supports one human being in peace and contentment; we use 10 acres for the same task.

We are told that the Chinese are careful to return all waste to the soil. So far is this carried, Professor King tells us (Farmers of Forty Centuries), that the water is not fit to drink without boiling. The Chinese drink tea not because they like tea better than water, but because boiled water is not palatable, and the Chinese hit on the idea of flavoring it with the leaves of a shrub that grows on their soils in great profusion.

The opponents of the theory of "immutable assets" assert that the soils of the Far East have held up under the tremendous strain put upon them because of the most careful system for the conservation of waste practiced by these people. Yet, in four thousand years the soils of China have produced a population mounting in the billions. Were the biblical injunction of "dust to dust, ashes to ashes" an actuality, then the earth would lose nothing because that which was earth would return to earth. The Chinese construct elaborate tombs for the preservation of their dead. Their religion teaches them not to violate with the plow-share the earth housing the bones of their ancestors; indeed, in some provinces in China the land occupied by tombs is more than one-half of the total.

China has always been an exporting nation. Of the three nations, China, Corea and Japan, only Japan has come in recent years to use chemicals as fertilizers, and she only in an experimental way. Why do these historic soils give no evidence of wearing out? The question cannot be answered by the "Theory of Mineral Requirements of Plants."

Right here at home we have only recently

come into the possession of authoritative evidence supporting the new hypothesis of "immutable assets," at least as applied to the growing of apples. The state experiment station at Geneva, New York, concluded fertilizer tests in the growing of apples in 1911, extending over a period of fifteen years. The data giving the results in detail is published in Bulletin 339 of the Geneva station.

The conclusion reached is that "on good soils, properly drained and tilled, and with the trees kept in healthy condition, the apple secures plenty of plant food for its needs and responds little, or not at all, to liberal fertilizing."

Quoting verbatim from the "conclusion" reached by these experimenters, whose results seem to be so much at variance with the orthodox method of growing fruit:

"The final conclusion must be that the trees in this experiment would be practically as well off in every respect had not an ounce of fertilizer been used about them. If fertilizers have no value for young trees in this orchard, they have no value in innumerable other orchards in New York. Fruit growers are spending money and losing time, as we

shall try to show in the next paragraph, in 'carrying coals to Newcastle.' Again it must be said that the soil in this orchard is about the same as the average apple lands in Western New York—no better, no worse. If there is any material difference, it is that this experiment plantation has been better tilled and better cared for in most respects than the average orchard. But the trees have not been coddled—the care has not been better than that given in the best commercial orchards. One of the lessons the experiments should teach is that fertilizers are not necessary in some soils if tillage and good care be the rule—the truth of the old adage that 'tillage is manure.' "

It is the opinion of the authors of this bulletin that "the soil must be a poor fruit type indeed, that will not, when properly handled, grow good crops of apples without artificial feeding."

The experimenters find that the upper twelve inches of soil in this experimental orchard contain enough nitrogen for 183 crops of apples, phosphoric acid for 295 years, and potash for 713 years. However, they are careful to avoid the position of seeming to favor the "immutable assets" hypothesis, even though their experiments seem to establish it.

They assert that this same soil responds readily to commercial fertilizers for garden crops and they explain the apparently contrary results in fruit growing by saying that the apple gets its food over a long season of growth; its roots run deeper and feed over a wide range; it transpires relatively large amounts of water, and can gather food from more dilute solutions than annual crops, and that its leaves return to the earth that produced them.

This bulletin, for all that its authors take a middle ground, was not well received by the agricultural press. In fact, it received as scant attention from the farm editors as has the federal Bureau of Soils hypothesis. In the face of the established facts of this test, one editor stated that "it is believed the experience of fruit growers is to the contrary."

CHAPTER IX

SOIL SANITATION

If the farmer possesses in his fields a mine of inexhaustible mineral resources, why is it that one field yields bountifully, while another does not repay the expense of seed?

Maybe the soil is tired.

If a man worked eight hours breaking stone, he is tired. He is *fatigued.*

What is fatigue? Fatigue is poison, it is a toxin secreted by muscles. This is a scientific fact well substantiated by research. There is nothing sensationally "yellow" in the articles that crop out now and again in the newspapers to the effect that "the germ of laziness" has been found. According to the newspapers, this "germ" has been run down to its lair at least a score of times in the last few years. The simple statement is almost scientific, in spite of the way the popular comic artists handle it. Fatigue has never been

isolated as a germ, but it has been isolated as a toxic substance. Fatigue in muscles of men and animals is not due to a lack of food in the muscles, blood or lymph. It is due rather to an excess of the products of metabolism. (Soil Fatigue, Oswald Schreiner and M. X. Sullivan, Jour. Biological Chemistry, Vol. VI.)

German scientists have been able to isolate a true toxin from the muscles of a tired dog. And, to show that fatigue in this instance was nothing more or less than a poison excreted by the muscles in the process of functioning, they injected this substance into the muscles of another dog. It brought about all the symptoms of fatigue in the second animal, although that animal was refreshed by a long sleep.

Thus, when we say a man is tired from breaking stone, we mean that his muscles have accumulated a waste product faster than phagocytes of the blood can carry it away. The action of the muscles becomes sluggish. It is like grit in the bearings of a machine.

Give the tired laborer rest, sunlight, fresh air—let him sleep—give the scavengers of the blood time to catch up with their task. Or, change his occupation. Let him do something

else. The result is all the same, generally speaking. If the laborer is tired out by one form of muscular exercise, give him a task that brings into play different muscles and he will be able to continue work.

This fact is recognized by the so-called efficiency engineers of the present day. They urge that laborers be given a rest every few hours, and, in addition, that they be given a change of employment occasionally. This runs counter to the old theory of division of labor, that a man is most efficient if he be permitted to do the same thing all the while. The old theory is easily explained by the axiom that practice makes perfect. The new theory, that a laborer should be given change of occupation, is based on physiological reasons, one might almost say pathological reasons.

The established fact that fatigue can be induced by chemical means suggested a new avenue of research to the scientists of the Federal Bureau of Soils, when they cast around to determine the causes of soil fertility and infertility.

Maybe the soil is tired. Maybe the soil is poisoned. Nature intervenes a season between crops, subjects the soil to freezing, thawing,

aeration, lets it sleep. Yet, if a soil be subjected to single-cropping for a generation or two, it will decline in productivity, although an analysis shows that it still has sufficient food for many crops. Maybe the soil needs a change of occupation, just as man. It is possible that the season of rest, intervened by Nature, is not sufficient to enable a soil to recuperate, if it is speeded at a fast rate. We know that fallow will restore the life of soil. Fallow is merely extending the period of rest, giving the soil more time to sleep. We also know that rotating crops, *giving the soil a change of occupation,* accomplishes somewhat similar results.

Is fatigue in the soil a poison, just as is fatigue in man and animals?

If such a suggestion could be established as an actual fact, it would explain at once many of the most perplexing problems in fertility. It would explain rotation of crops as "change of occupation," it would explain fallow as "rest" or "sleep," and it would explain the benefits due to cultivation, in addition to conserving moisture, as bringing light and air into the soil to rejuvenate it.

There is a set of interesting experiments

which any farmer may conduct by himself. They were suggested to the scientists of the Bureau of Soils, by the possibility that there does actually exist a parallel between the fatigue of a man's muscles and the fatigue of the soil.

Wheat seedlings were grown in a rich, sandy soil, under glass, in a greenhouse. The soil contained much richness; temperature and moisture could be controlled within narrow limits; and, to keep the body of soil used in the experiment separate, it was inclosed in a wire basket dipped in parafine. This form of pot is better than the usual one, as it contains no air space between the soil and pot, and the roots do not, therefore, cluster about the edges, but penetrate the mass, as they do under actual field conditions. In this experiment every effort was made to reproduce actual field conditions.

The wheat was allowed to grow for several weeks in the wire pot and then was pulled up and thrown away. Immediately thereafter, another crop of wheat seedlings was planted in the same soil and urged to growth under the same conditions.

The peculiar thing about it was that this

second crop of wheat did not thrive. It came up sickly and spindling, like a child in the bad air of the tenements. Had this second crop been part of a wheat field, the crop would have been called a failure.

Why did this second crop of wheat fail to grow thriftily? The soil contained hundreds of times the amount of "plant food" necessary for its growth. "Weather" conditions, that prime factor, were the best. Yet it did not grow.

Repeated attempts failed to produce a second crop of wheat as good as the first. The soil was like a tired laborer who had worked a full shift. He is incapable of continuing his task with zest. So with the soil.

Then this pot of soil was given a "change of occupation." It was planted again, but not to wheat this time. Instead, it was planted to cow-peas. The cow-peas grew lustily! The soil that could not produce a second crop of wheat produced cow-peas as thrifty as if they had been grown on virgin loam under ideal conditions.

But a second crop of cow-peas was less successful. It was like the second crop of wheat. Wheat following wheat without intermission

failed, just as cow-peas following cow-peas without intermission failed.

Then this soil, which first refused to grow a second crop of wheat, but grew a crop of cow-peas, and then refused to produce a second crop, responded readily when it was asked to take care of a potato seedling. Thus, in succession it would grow wheat, cow-peas and potatoes, but not a second crop of either in succession.

After the potato sprout had thrived it was taken from this pot and a wheat seedling was planted. It grew to perfection!

Thus, wheat would not follow wheat, but when two other crops had intervened, the soil responded to wheat as readily as it had in the first place.

Had the originators of this simple experiment stumbled on the secret of the good usage of crop rotation? The same conditions are met with in field practice. Old land, well manured though it may be, sickens, gets tired, when it is asked to grow one crop season after season. But when the crop is changed every year the soil responds perfectly. The same crop can be grown continuously every third or fourth year without diminution of yield,

but it cannot be grown successfully every year without a quick drop in productivity. Here is a factor in fertility, or the lack of it, in which "plant food" as such plays no part.

In attempting to explain the peculiar behavior of this pot of soil, all of the usual factors could be set aside. The soil was rich in minerals, its organic content was maintained, it was well watered, and the temperature was at the optimum for the production of these crops. Going back to the analogy of the tired laborer with poison in his muscles, it was suggested that this soil was tired. It was given no rest between crops. In nature, seasons intervene, to give the recuperative agencies of the soil a chance to work. Even if such agencies were present here, they were given no opportunity to work.

The experimenters set about looking for the *poison of fatigue* in this pot of soil. To concentrate this "poison," supposing it to exist, they forced the pots to grow several crops of wheat and cow-peas in succession. Then they took the soil and subjected it to analysis. They isolated crystalline substances from these soils that had grown tired of growing wheat and cow-peas. Searching for the same substances

in soils that had not grown "tired" of these plants, they could not find them. Apparently they did not exist. Apparently they were the product of the growing plant or the product of the soil in its process of functioning to produce this plant.

If these substances really were the "poison of fatigue," as applied to wheat and cow-peas respectively, a demonstration of the truth ought to be simple enough. A soil solution, either extracted from a healthy soil or put together synthetically in the laboratory, was treated with an "injection" of the "poison" isolated from the soil that was sick of growing cow-peas. Then cow-pea seedlings were introduced. Ordinarily these grow well in water. *But they did not grow at all in the water which had been treated with "poison."*

The same result was obtained with wheat seedlings, in a solution treated with the wheat "poison."

On the other hand, cow-peas grew well in the solution inhibitory to wheat, and wheat grew well in the solution that would not grow peas. Apparently the poison was peculiar to each family, inhibitory only to its own family of plants.

This conclusion is borne out in actual farm practice. The average farmer is familiar with the curious phenomena of "sick" soils—soils that seem "sick" in so far as they refuse to grow certain crops. Flax, it is generally assumed, is wearing on soils subjected continuously to its production. Those soils which tire of growing flax are not deficient in the mineral elements of fertility, as is easily proved by planting them to other crops. The so-called "clover-sick" soil is another instance. Almost every farmer has seen within his own experience a plot of land that once grew clover well suddenly become sterile as regards this plant.

Reclaimed swamp soils seem particularly susceptible to this so-called "sickness." In the corn belt it is not unusual to see such soils break down in the course of two or three years' continuous cropping of corn, yet it is known that their innate fertility measured in minerals is high. In California reclaimed soils that grew mammoth crops of potatoes at first have frequently become unprofitable for potato culture. Yet they respond admirably to other crops.

In the laboratory tests, the task of restoring this sick soil to its original fertility as

regards any crop proved exceedingly simple, just as it has in actual field practice.

Part of the test soil was baked in an oven. Nature does the same thing by prolonged periods of drought. After the artificial "drought" the soil became productive again.

Boiling had the same effect. Boiling means sterilization. Treating it with charcoal, bone-black, lime, ordinary "pyro," used in photography, freezing it, any of these methods had the same effect. Exposing it to sunlight and air—tillage—and mixing it with organic manures which are subject to rapid decay were other methods adopted with equal success.

What does the intelligent farmer do in actual practice?

He rotates his crops. We have seen that rotating crops in the experiments seemed to do away with the toxic substances or at least with their effects.

He applies stable manure. He plows under green crops. He tells himself that in so doing he is adding "plant food" to the soil and he accepts the word of the expert as to how many pounds of minerals he is adding thus, and he usually overlooks the fact, which the expert seeks to impress on him, that barn-

yard manure as usually handled loses more than half of its soluble minerals before it is scattered on the field.

The toxic soil solution that was benefited by the use of "manures" did not require plant food. The effect of the manuring must then be from some other cause. It is due to the fact that the decaying organic substance liberates oxygen in an active form, which is able to destroy the "poison" of the soil.

The farmer plows, harrows, cultivates. Tillage, he is told, conserves moisture. In addition to conserving moisture, it aerates the soil, lets in the air and sunlight.

The farmer under-drains his fields. Under-drainage removes excess moisture, and in doing so opens channels through which the air may circulate.

And in addition to these practices Nature steps in and intervenes seasons of rest for the soil. The toxic soil under test was found to be restored to fertility by a short period of rest.

Study the methods of a successful farmer and compare them with the methods used by the scientists in this laboratory test and you will see that they follow parallel. Live-stock

farming is recognized as one of the highest types because of the immense amount of organic refuse it enables the husbandman to return to the soil.

Yet, when we analyze stable manure, the best of all fertilizers, we do not find large quantities of nitrogen, potash, or phosphoric acid even under the most favorable conditions. Stable manure is admitted to have a fertilizing effect on land far in excess of what can be computed from an analysis. In England it is a common practice to charge a fresh dressing of manure against a new tenant for seven years. In a long continued investigation in our own country, it was found that 96 per cent. of soils responded better to organic manures than to mineral fertilizers in commercial form.

Our western prairies are rich with the decaying mold of thousands of generations. Nature practices a rotation of her own. First comes the process of selection, in which the plants best suited to the soil survive and persist, while the others perish. In time each month of the growing season comes to have its peculiar plant. This is illustrated by the succession of weeds in an uncared-for garden.

Even in forests Nature rotates her crops. Pine and oak alternate, as every woodsman knows.

If Nature had no other means than crude rotation the soil would soon cease producing vegetation. In fact, it would never arrive at the point of selecting its own cycle of rotation.

But Nature has another means. She *feeds* her soil. She does not feed it with "plant food," as expressed in pounds of minerals, but she stuffs it with dead fiber, which, in the process of decay, exercises the same influences, though in a less active form, as barn-yard manure or green crops plowed under. In the process of decay the oxidizing and nitrifying substances are set to work, "cleansing" the soil of the toxic compounds formed during the process of growth.

The prairie soil is "loam" not because of the fine mineral particles it contains, but because of the content of decaying organic substances. The best practice of farming teaches that the soils should be kept stuffed with decaying vegetation in one form or another. The prairies, over the ages of their wild existence, were able to store up a tremendous reserve of these sanitary agencies. So great was this

reserve that it took a greedy nation of pioneers a generation or two to break down the power of the soil to recover itself with the natural rest of the seasons. Corn followed corn, wheat followed wheat in the fifty years following the opening of the West to settlement. Crop yields began to decline eventually, and the careless farmer, content with the theory that Nature had been parsimonious with the mineral ingredients, turned to the fertilizer bag. The fact that chemical fertilizers act as a tonic to tired soils was sufficient proof to the farmer in the field that the theory of Liebig was right.

Crop rotation was forced on our farmers only when weeds, driven from their happy hunting grounds by the plow, returned and adapted themselves to the new conditions and reproduced themselves in profusion. When a farmer's oat field became so foul that the weeds clogged his machinery, the farmer plowed his oat field and put in corn. There was no other *rationale* behind the process so far as he was concerned. Even to-day nine-tenths of our wheat comes from single-cropped acres. In the Dakotas, among the "jumbo" wheat ranches, it is customary to give the soil a year's

rest—fallow—when it begins to show signs of breaking down under single-cropping. In the Great Plains area extensive farming has called for the manufacture of machines that "head" the grain, leaving the stalks standing, to be plowed under by the gang plows which frequently are drawn by the same motive power that cuts the heads and threshes the grain. This is done merely because it is convenient, because it is the most economical means of farming in that region; the fact that returning the dry stalk to the land is beneficial is merely incidental. The straw is a drug on the market and plowing it under is the easiest means of getting rid of it. It is said that four mules are required for the same plowing that required only two twenty years ago in some parts of the irrigated districts in the West. This means that the soil has become less friable, has lost its optimum content of mold, is no longer "loam," because of a system of farming which concerns itself more with the mineral fertility than the organic content of soils.

The organic content of soils amounts usually to about three per cent. of the entire bulk. It is not assumed that the only or even the principal use of this mold is that of ridding

the soil of toxins. Even aside from this property, which exists merely as a hypothesis at present, the organic material of soils exercises a tremendous part in fertility.

A soil containing the proper mixture of decaying vegetation has superior moisture-holding properties, and moisture is the life-blood of the plant. And we have seen that decaying vegetation furnishes not only food for the plant, but food for the microflora and microfauna of the soil, as well. The instance cited of the use of carbonaceous débris, such as rotting turnips, as food for the bacteria which fix nitrogen from the air in a form available for the use of plants, is an illustration of this part played by the organic content.

The soil is not a dead thing, according to the latest conception, but a thing teeming with life, both plant and animal, and these microscopic creatures and plants have a dual rôle to perform. They feed the growing plant with palatable food, and, at the same time, act as scavengers of the soil. They, in turn, depend for their healthy activities, not on the mineral content of the soil, but on the organic content. The soil must be sweet, if we would "domesticate" these agencies and use them

to the best advantage. Therefore, we apply lime.

It is doubtful if normal soils are deficient in lime so far as plants require it as a mineral food. Some crops, such as the legumes, are heavy feeders of lime and require that a balance be maintained by actually adding lime in exceptional instances. But by far the most important function of lime is to cleanse the soil and make it habitable for the hosts of bacteria which are at work therein.

It is a common experience with farmers on soils that have been heavily cropped for many years to see alfalfa or clover fail utterly unless lime be added and harrowed into the soil. An analysis of that soil would probably show that calcium carbonate was present in sufficient quantities to feed the legume. But a test of the soil with litmus paper would show that the acids of the soil, the ferments of decaying green vegetation not properly controlled, had rendered the soil "sour," as the saying goes. "Sour" soil will not grow legumes; although, on the other hand, it is considered necessary by many farmers for growing potatoes without scab. Potatoes can be grown on the same soil year after year, if green rye or other green

manure be plowed under in the spring and be given a chance to ferment.

But to grow the legumes successfully, it is necessary that the bacteria which inhabit the nodules on the roots of these plants are given a chance to work amid sanitary surroundings. The soil must be "sweet" else the nitrogen-fixing bacteria, which may add as much as 200 pounds of nitrogen to an acre of land in an ordinary clover crop, will die. And, in addition, unless the decaying mold of the soil can feed these same bacteria on starches in return for their nitrates, the bacteria are useless as a factor in soil fertility.

The knowledge of bacteria, molds and enzymes as affecting fertility is still fragmentary. Scientists have isolated a few forms or "races" of microscopic plants and animals and determined their part in soil fertility and the conditions under which they thrive. There are other forms which, under conditions favorable to their culture, render the most fertile soils sterile. Professor Hall well says that the farmer of the future must domesticate these unseen life-forms, encouraging the helpful organisms and doing away with those that are harmful.

The belief that the process of producing crops on a soil causes the formation of toxins is not new. De Candolle suggested, in 1832, that plant roots excrete a poison which sooner or later would render any soil sterile if subjected to single-cropping. (Physiologie Végétale, Paris, 1832.) Liebig accepted this explanation as the true one at first, but later began his researches in the mineral requirements of plants and abandoned his original position. Once his Theory of the Mineral Requirements of Plants became adopted the suggestion of de Candolle was forgotten. Only when American scientists turned their attention again to the part played by the organic elements of the soil was this suggestion examined in detail or with any seriousness of purpose.

Even to-day our own scientists do not accept de Candolle's suggestion literally. They admit they have isolated substances from soils following plant growth, but they are not ready to admit that these substances are the result of root excreta. In several instances the facts seem to point to that explanation. In others, however, the origin of these substances is much more complex. They may be the result of

ferments of organic matter, or the result of the action of bacteria or fungi, as these agencies are related to plant growth.

The fact, however, that deleterious substances are to be found in soils that have been cropped set a task for the scientists of the Bureau of Soils. That task was to examine soils, both productive and non-productive, from a wide range of samples and to isolate compounds to be found therein. This is the present task of the Bureau of Soils, and it is a work requiring the best powers of chemists. It is one thing to discover the presence of a complex compound in a given soil or a soil solution; and it is quite another to isolate that compound. Over fifty compounds have been isolated at this writing, and each is being tested separately for its effect on productive soils and its action under different treatments, including the application of mineral fertilizers. Already there is a wealth of data on the subject, in scientific form, and gradually broad principles of soil fertility are being put forward as theories and efforts being made to check these theories by actual practice.

The most widely found toxin is a compound known technically as dihydroxystearic acid.

It is a fatty acid, as its name implies, and has been found, almost without exception, in all samples of infertile soil that have come under the examination of the Bureau of Soils. Shall we say that here we have isolated the "germ of sterility"? That would scarcely be justified, except in a journalistic sense; yet it has now been established that an injection of this compound in any soil *will render that soil unproductive.*

This acid has been known to science for a long time, but merely as a laboratory product. That it was being produced in soils and caused them to be infertile was a distinct addition to knowledge. Again here, as with the toxins isolated from the cow-pea and wheat soils, sterilizing or sanitary agents are found to restore the soil to productivity. Furthermore, the addition of mineral fertilizer salts to solutions rendered sterile by this compound is found to have the same effect.

Not all salts act equally well in restoring this "sick" soil to condition. Potash and phosphoric acid seem to have little, if any, effect. But nitrogen, in the form of nitrate of soda, which costs the farmer about 18 cents a pound, seemed to neutralize the effects of the

dihydroxystearic acid entirely. Here, then, is a use of chemical fertilizers not explained by the "plant food" theory.

On the other hand, there are other substances found in normal soils which are rendered even more toxic by the addition of nitrates. These substances are, for the most part, nitrogenous themselves. As an instance, a substance called cumarin is found to have a very characteristic effect on plants, stunting the growth and distorting the leaves. The addition of nitrogen or potash does not affect it at all. Yet the addition of even a minute quantity of a phosphate salt clears the soil of this toxin and a healthy plant is produced. Potash salts affect still another series of toxic substances.

In presenting in detail the history of his investigations of this phase of soil fertility before the American Association for the Advancement of Science, at a recent Washington meeting, Doctor Oswald Schreiner was led to remark:

"These actions of the different fertilizer combinations, or different fertilizer requirements, as they may be styled, show a certain parallelism with field observations on soils and

their fertilizer requirements, and one is tempted to ask to what extent the different fertilizer requirements of different soils, or of the same soil under different conditions, may be influenced by the same cause. That harmful bodies occur in soils has been amply shown, and that these are influenced directly or indirectly by fertilizer salts is also clear from these and other researches.

"That the constitution of the organic matter varies from soil to soil and in the same soil under different conditions of aeration, drainage, and cropping is likewise clear. The presence of compounds inimical to plant growth by virtue of a property resembling that of any of the above-mentioned substances might, therefore, cause a different fertilizer requirement, a requirement which might even change from time to time, according to the nature of the biochemical relations producing the body or according to the nature of the plant remains in the soil; in other words, according to the rotation, with its necessary altered soil management, and the altered biochemical changes produced in the different plant remains."

* * * * *

"Organic matter is very changeable; it is the material which forms the food, as it were, of all the microörganisms of the soil, of the bacteria, of the molds, of the protozoa, and in-

fluences them favorably or unfavorably, just as the higher plants are affected. In turn, these agents are great promoters of these changes in the organic débris of soil. All of these processes and the life forms in the soil are affected by fertilizer salts when added to the soil, and changes are produced in the soil, physical, chemical, and biochemical, which influence the soil and affect its potential fertility entirely irrespective of the added plant food. In other words, the soil has been changed in many prominent characteristics even before any crop is planted therein.

"I must not leave this subject of fertilizer action, in view of the preceding paper, without saying that the Bureau of Soils takes an advanced stand not only on the present use of fertilizers, but on their extension in agriculture, in spite of the reiterated statements to the contrary."

* * * * *

"We believe that these additional—note particularly that I say additional—actions explain more fully the function of fertilizers in agriculture. From the former view the application of fertilizers would be restricted to poor and so-called exhausted soils and poor systems of agriculture; from the latter viewpoint, fertilizers are indicated as well for fertile as for infertile soils, as an adjunct to

successful farming and bringing the soil to its highest capacity of crop production."

In addition to the injurious substances to be found in soils, there are others, such as creatinine, which seem to exercise a positive tonic action on crops. Among these are many nitrogenous substances which seem to be the result either of root excreta of growing plants, or the result of the decomposition of green manures, barnyard manure, and many other organic compounds used as fertilizers. Leguminous crops are especially rich in some of these rare compounds, and the isolation of these substances from soils growing legumes adds another argument to the sum of benefits of a practice thousands of years old.

As to the origin of this class of compounds, both toxic and tonic, little definite is known. It is certain that several of the compounds are the result of root excretions. Others result from the breaking down of organic débris present in the soil independent of that left by crops. Still others are the result of the débris left by roots of plants, and whether or not, in this connection, each family of plants actually does leave in the soil residues inimical to its

own kind is mere speculation. In the case of cow-peas the facts seem to warrant such an assumption.

This phase of the researches of the American scientists has met with even more skepticism than that pertaining to the "immutable assets." Yet the opponents come to the line of battle singularly ignorant, because the United States Bureau of Soils is many years ahead of the others in research along these lines. In fact, all of the original research that has been conducted to this day has been on the part of the Americans, working in their Washington laboratories.

The position of the opponents is that of agnostics. They do not know. Therefore, they do not believe. Scientists of Rothamsted are inclined to dismiss the postulates without argument. So far as their personal knowledge extends, there are but two classes of soil—soils that are sour and soils that are sweet—in other words, soils containing a sufficiency of calcium carbonate and soils deficient in this element.

They are inclined to believe that many of the phenomena listed by the Americans as due to organic toxins in soils are due merely to a

"sour" condition of these soils. The mere fact that in the majority of cases lime restores such soils to fertility is sufficient proof to their minds that such soils are simply "sour."

The answer to such a contention is, of course, obvious, no matter what ground a student may take as to the value of these researches of the Americans. Lime, it is true, does remedy matters in most instances. But many other compounds have the same property. And the majority of these compounds do not possess the additional property of rendering sour soils sweet. Green crops, for instance, will render soils acid, yet they have the property of accomplishing the same results with many of these toxins as lime. In the case of the Agdell field at Rothamsted, where simple rotation without manures of any kind grows more wheat than continuous cropping with complete fertilizers, the men of Rothamsted station say:

"We cannot accept the explanation of the Americans, yet we have no theory to offer in exchange."

CONCLUSION

It is remarkable that two such widely divergent explanations of the fundamentals of soil fertility as the Liebig theory and the more recent hypothesis of the American scientists should have any common meeting ground.

Yet the two systems advocate identical methods, and, with the exception of that phase of the subject dealing with soil toxins, they are founded on the same historical data. It is not how our Jeremiahs shall farm that is in dispute. So far as the farmer in the field is concerned, he may go on following accepted traditions in agriculture and the chances are that he will never come violently in contact with either theory, either as cause or effect.

Agriculture as a science is of recent origin; whereas agriculture as an art dates back to the beginning of history and has accumulated a mass of tradition founded on experience, which science seeks to explain and extend. As

an example, take the growing of clover in the farm rotation. For several hundred years the farmers of the Far East have made a practice of growing clover and grain in alternate rows. The rationale of the practice was simply that they had discovered, in terms of money loss or gain, that grain removed an element from the soil which the legume restored. It was not necessary for them to "take the works apart" to find out what made the wheels go round. It was quite sufficient to them that good results did follow such practice, as time had verified to their satisfaction.

The Western nation, however, is not satisfied to see an effect without investigating the cause. Hellriegel took the works apart, so to speak, and showed us that the root nodules of the legumes contained nitrogen-fixing bacteria. With this secret in hand, we were able to isolate the families of bacteria peculiar to each legume, and, once having isolated them, to propagate them and scatter them on our plowed fields in profusion.

Nevertheless, having learned the why of the process, still we have not been able to surpass the farmer of Asia in the intelligent use of legumes. Every advance that science suggests

we find already in practice among these wonderful people not as science, but as art.

The rotation of crops is indicated as necessary to successful farming for the purpose of keeping the fields clean and free from noxious weeds, even aside from any scientific theory regarding the balance of available mineral nutrients or the eradication of soil toxins.

Tillage conserves moisture, and the farmer will continue to cultivate his land, satisfied with the good effects to be derived therefrom, and meantime the different schools may fight out the problem of whether tillage has the additional function of liberating "plant-food" or acts as a sterilizing agent to rid a soil of noxious compounds.

Live-stock farming will always represent the highest efficiency in agriculture, no matter what the cause may be determined to be by science in the end. If the application of organic manures, including green crops plowed under, owes its good effects to the "plant food" as such, or to its power of oxidation (sterilizing) and nitrifying, or to a middle ground embracing the two, the practice still remains established. So with the use of lime and the mineral fertilizers, including phos-

phoric acid and the salts of potash. There is no quarrel over the practice.

One point, however, stands out clearly, and that is that the use of minerals as fertilizers, whatever may be their effect, is little understood by either side of the controversy, and a great deal of money is being wasted by their indiscriminate use. The fact that in a long series of tests ninety-six soils out of every one hundred responded better to organic manures and lime than to phosphoric acid and potash, while only four soils out of every one hundred favored the minerals, should indicate to the farmer that the evidence at the present time is overwhelmingly in favor of the organic manures.

Hopkins, the most advanced of the adherents to the theory of Liebig, says the farmer need add only phosphoric acid if he practice the accepted system of farming. The organic manures and the microflora and fauna of the soil, properly controlled, provide nitrogen; and potash, except in rare instances, such as some reclaimed swamp soils, is not wanting. Yet, if the farmer seek among the records, he finds plenty of data which seems to indicate potash, as, for instance, in coloring fruit.

In tabulating the results of thousands of experiments with mineral fertilizing, conducted by official experiment stations, the experts of the Bureau of Soils made the interesting discovery that, in the majority of instances where increased yields of different crops were attained, the cost of the commercial fertilizers was more than the value of the increase in yield. The same set of experiments, however, showed that smaller amount of fertilizers, applied in combinations of three, two, or one ingredient for different conditions, would have brought about the same increase. If it costs more to carry coal to Newcastle than the carrier can get for the coal, the practice is futile, no matter on what theory it may be urged.

The question the farmer asks himself is, does it pay? Does it pay to-day and will it pay to-morrow? He is not an idealist. He is in the highest sense a business man engaged in manufacturing a commodity, food, for which there is a definite demand. If it costs him more to feed his soil than he can recover in dollars and cents he will go out of business. He will not wait for the soil to quit. He is subsidized, but not to that extent.

The American farmer possesses to-day a

knowledge of all the practices in the art of agriculture which have enabled older nations to meet growing demands of hunger. If science should stand still, in fact, if the science of agriculture should be expunged, still there exist traditions which give the secret of feeding ten or twenty times as many people to the square mile as we are feeding to-day. We are coming to look to the people of the Far East more and more, and in time it will become a national function to study these people and set forth their precepts and examples for the benefit of our Jeremiahs. Only in recent years have we come to view anxiously the vast quantities of silt carried to the sea and irretrievably lost by our rivers. We are told that 4,100 years ago Emperor Yao appointed the Great Yu "superintendent of the works" in China to conserve the waste of flood, and he devised a system of canalization and impounding the surplus water of freshets, so that the erosion of mountains might be used to build delta land at the lower levels. King tells us that many of the cities of China have been steadily moving away from the seashore where they were originally built by this conservation of the waste of

erosion, until now one travels for fifty miles in some instances through fertile fields from the sea to the city that was once a seaport. Japanese fields are ridged into basins to catch the erosion from the surrounding hills. Surplus water must pass *through* their soils instead of *over* them, and in percolating it must leave behind its burden of silt instead of carrying more away.

First the utilization of every foot of available land; then the adaptation of crops to the soil and climate and intensive cultivation by a combination of dry-land methods and irrigation; and then maintaining the organic content of the land by a religious conservation of waste. By these means the people of the East manage to live in contentment with no thought of impending doom after more than four thousand years. Whatever may be the explanation of the fact that Chinese soils have not worn out, it is certain that sooner or later the West will be forced to adopt similar measures to increase the productivity of their acres. We preach that live-stock farming is the highest form of agriculture because it enables us to return the animal excrement to the fields; yet in our cities we are expending huge sums an-

nually to dispose of sewage, the highest and most active form of "fertilizer."

If we can judge by the history of other nations, the problems of the next few hundred years, so far as food supply is concerned, are not in the least terrifying. Compared with the older nations, the American farmer has not yet begun to farm. Without intensifying his methods, the American farmer still possesses enough raw land to support twice the population he is supporting to-day. In another fifty years we will have attained this population at the present rate of increase.

Of the land nominally in farms at the present day, there are available ten acres to feed one human being. The millions of China thrive in content, with an allotment of less than one-half acre to every soul, and when we shall have attained a population ten times as dense as it is to-day, when we shall have crossed the billion mark, still we will possess twice as much food resources measured in terms of cultivable land as does Japan at the present day.

In Germany the services of one farm laborer are required for every nine acres of land. In the United States our speed is still so slow

that one laborer takes care of forty acres of land.

How much food will an acre produce? We have no means of measuring this except by examining the most crowded acres of the world. Professor F. H. King relates an instance he encountered in China, by no means unusual in that country, of a plot of 2½ acres supporting a farmer and his family of twelve, with one donkey, one cow, and two pigs. This means a density of 3,072 human beings, 256 donkeys, 256 cattle, and 512 swine to the square mile. Japan maintained a population of 47,000,000 in 1907 on the food produced by 20,000 square miles of cultivated land, or at the rate of three people to the acre and 2,349 to the square mile. Draw a line, says Professor King, from Chicago to the Gulf and another to the western boundary of Kansas and complete the rectangle thus formed and we have the area of cultivated land from which the 500,000,000 of China, Japan and Corea get their food.

Viewed in the light of these comparisons, the exhaustion of the resources of our soil is remote indeed.

THE END.

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